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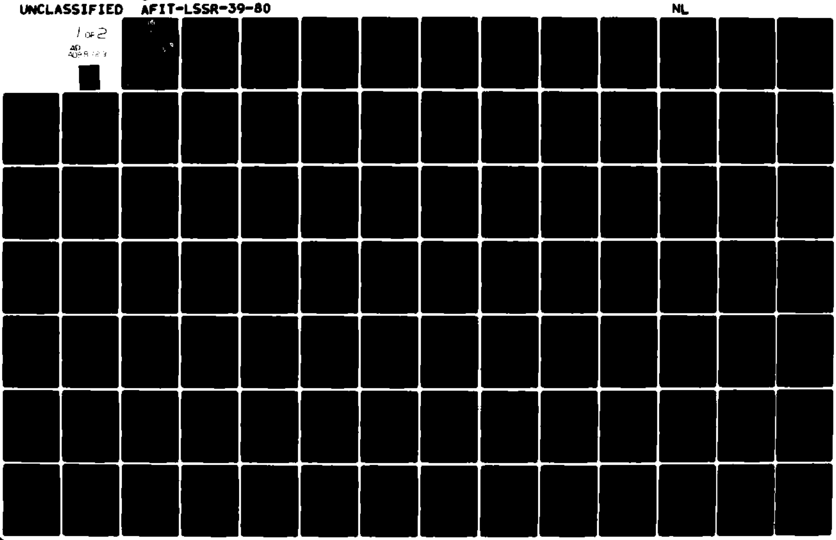

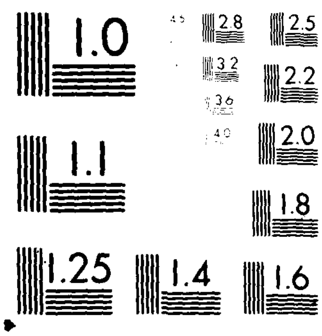

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RESPONSIVENESS AND CONFIGURATION
CONTROL FOR EMBEDDED
COMPUTER SOFTWARE

Gerald O. Wade, GS-12

LSSR 39-80

USAF SCN 75-20B AFIT Control Number LSSR 39-80

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The purpose of this research effort was to (1) determine those factors contributing to the inability of the Air Force Logistics Command (AFLC) to provide responsive support to Embedded Computer Software users which has the appropriate degree of control exercised and (2) determine the management system structure and factors required to provide responsive support of controlled software. The research has three phases. The first is a discussion of software management principles essential to effective software management. The second is comprised of models of three distinct management systems and analyses each of terms of benefits, deficiencies, operating policy, application of software management principles, and provides comparative conclusions on which aspects of a management system were the best. The third is an analysis of the results of the interaction of the software management principles and a management system and discusses those principles of relative importance to a management system processing stage. Conclusions developed were that responsiveness problems experienced in AFLC were attributable to its utilization of change blocking, the G026 management system, and its management system's structure. Recommendations were that ECS requirements should take priority, minimal management layering should exist, and explicit responsibility and authority delineation is defined.

LSSR 39-80

RESPONSIVENESS AND CONFIGURATION CONTROL FOR EMBEDDED COMPUTER SOFTWARE

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics Management

By

Gerald O. Wade, BS
GS-12

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This thesis, written by

Mr. Gerald O. Wade

has been accepted by the undersigned on behalf of the faculty of the School of Systems and Logistics in partial fulfillment of the requirements for the degree of

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DATE: 6 June 1980

William A. [illegible]

COMMITTEE CHAIRMAN

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The systems analysis techniques utilized in this effort are the result of Lieutenant Colonel Thomas Clark's guidance of such to management structures. Because of his instruction and guidance, this investigation of Embedded Computer Software management was enhanced.

It is because of my wife's understanding, patience, and support that I was able to devote much time to this effort. Without her, this effort would not have been accomplished.

TABLE OF CONTENTS

Page

Page

LIST OF TABLES

LIST OF FIGURES

Chapter I

INTRODUCTION

The ability to enhance in real time the operational capability of a deployed weapon system has been a long term objective of weapon system users. The utilization of Embedded Computer Software (ECS) in a weapon system has facilitated this objective. ECS provides the ability to precisely tailor a weapon system to specific operational requirements in near real-time. ECS is that software that is an integral part of an electro-mechanical system embedded in a weapon system such as combat weapon system, aircraft, ship, missile, spacecraft, and command and control systems (2:i). As a result of ECS's enhancement capability, the management system to be utilized for ECS is of equal importance to both the weapon system user(s) and any organization assigned ECS support.

In considering a management system for ECS, three highly visible factors associated with ECS have a direct bearing on the management system selected. These factors are Life-Cycle-Costs, software configuration control, and responsiveness to changing operational requirements. Concerning Life-Cycle-Costs, ECS procurement costs are estimated to be one-fourth to one-fifth of the entire costs associated with current ECS acquisition (1:9). In addition, the

percentage of total weapon system costs directly attributable to ECS is increasing at an extraordinary rate while weapon system hardware costs are decreasing. Current estimates for ECS costs are illustrated by Figure 1.

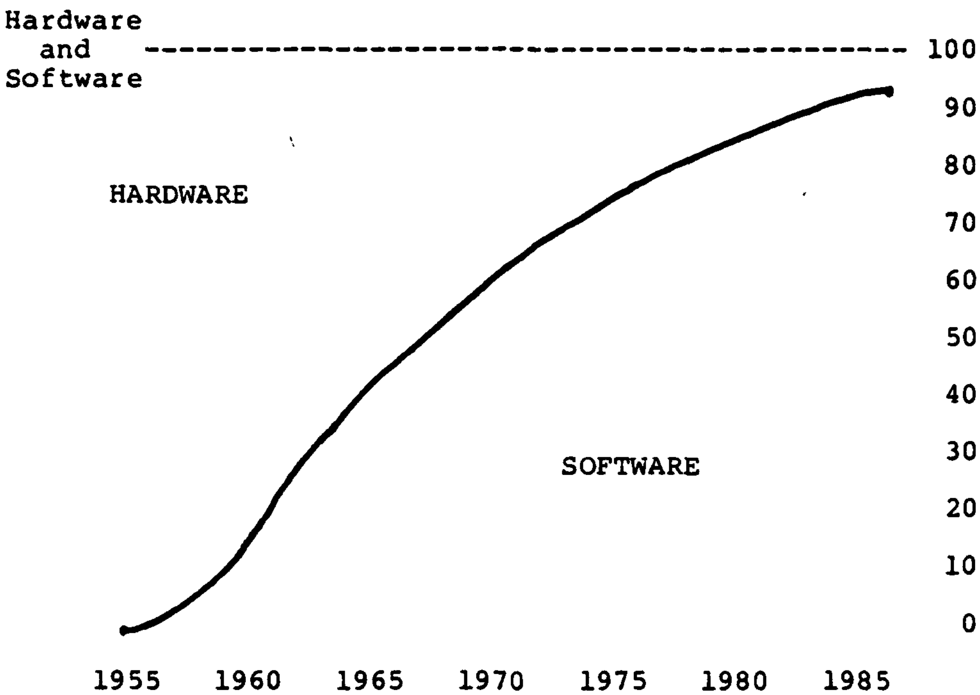

Figure 1

Percentage of Software and Hardware Costs of Total System Acquisition Costs (23:39)

The major contributing factor to Life-Cycle-Costs is software configuration changes. Typically, a previously believed correct and tested ECS program will suddenly produce wrong results, no results, behave erratically as a result of stimuli not previously addressed nor accounted for in the programming effort (7:18). This situation will

result in extensive program delays, software program reiterations, and major modifications. A specific example is the Strategic Air Command's Automated Command Control System where errors were discovered at a rate of one per day and eventually 95 per cent of the software had to be rewritten (23:38). For another system currently under procurement consideration, the anticipated ratio was fifteen to one for software changes to hardware changes (1:14). ECS change responsiveness and control are the critical considerations in any ECS management system since changes are critical to the successful employment of a weapon system. The successful employment of a weapon system is, sometimes, dependent on the support organization's ability to tailor the ECS to operational requirements in a timely, efficient, and effective manner. Operational requirements are user determined and responsiveness to these requirements is a major factor in ECS management. Responsiveness is defined to be that time from the identification of an operational requirement or software deficiency to the return of the weapon system to an operational state with the appropriate software changes incorporated. From the user's viewpoint, responsiveness is the deciding issue in any ECS management system. For users, the criteria, in order of precedence, for evaluating a support organization's responsiveness effectiveness is: (1) timely satisfaction of mission requirements, (2) implementation of DOD policies, and (3) effective utilization of personnel and weapon system (1:8).

The AFLC position regarding ECS management is that software must be maintained as part of the overall weapon system's System Management and System Engineering responsibility (1:8). However, a recent AFLC study concerning Communications-Electronics-Meteorological systems did not address the current AFLC management and support practices capability of providing the responsiveness required by users (1:6). Instead of addressing software responsiveness, AFLC has recently issued direction to utilize hardware management and support requirements for software. Failure to recognize the unique characteristics of software and to plan to manage it as "just another system" negates the basic benefits of ECS (1:12).

In order to obtain the most economical, efficient, and effective management of ECS, reasonable tradeoffs are required between responsiveness and configuration control. The management concept utilized should treat ECS and the weapon system as an integrated entity insuring to the user maximum design flexibility, responsiveness to mission requirements, weapon system integrity, and interoperability (1:12). This management concept to be utilized for software has been stated as:

> This policy concerns configuration management of computer resources in major defense systems . . . . Software will be treated as a full fledged configuration item, with all required disciplines, controls, and testing included. The emphasis will be on product definition, requirements traceability, interface definition and control, cost, quality traceability, and the corollary control disciplines [1:9].

PROBLEM STATEMENT

Current AFLC Management System requirements for post-Program Management Responsibility Transferred ECS adversely affects responsiveness to User configuration changes for tailoring a weapon system to an operational requirement.

BACKGROUND

Currently, decisions on which command will ultimately manage ECS have been made on a case by case basis (31:9). This situation is due to the strenuous objections placed by weapon system users to the centralization of ECS management in AFLC. User objections focus on one central issue, responsiveness. The AFLC approach to provide responsiveness and configuration control is to utilize the System Management concept (1:10). This concept functions within the existing AFLC hardware-oriented roles, missions, regulations, and policies (1:7). This approach to software management does not provide the degree of responsiveness required by users. Traditionally, this inability by AFLC has been attributed to inadequate or nonexistent ECS documentation. However, users do not seemingly experience a similar problem for the software they manage. Each major command, in an evaluation of a recent proposal for centralization of Communication-Electrical-Meteorological (CEM) management in AFLC, identified responsiveness as the critical issue. AFLC did not and does not address this deciding user issue.

JUSTIFICATION OF RESEARCH EFFORT

Software design is extremely complex, requiring extensive self-documentation and program readability (23:39). Because of this, software management is personnel dependent, program documentation dependent, unrewarding, and stress inducing. This management complexity is further complicated the multi-command management responsibility currently utilized with ECS. This complexity has accentuated rhe requirement for the total system management of a weapon system. ECS needs to be integrated within the overall system management function of the weapon system (1:8). In AFLC, the key elements required to assure that user's ECS responsiveness requirements are attained and that the ECS's configuration is controlled are System Management, System Engineering, and System Configuration Management. The lead function is System Management. The System Management's function is to assure effective, efficient, and economical support to ECS users that is responsive and within economical constraints. System Engineering's function is to direct and control the totally integrated engineering effort required to support all aspects of the weapon system (1:10). The dominant criteria through both of these functions is the assessment and assignement of priorities to insure consonance between user's responsiveness requirements and AFLC support considerations by providing the responsiveness and control required by all involved organizations. This priorities

assessment and assignment is to be accomplished through minimal management layering of personnel and management tools between the user and the System Manager (1:13). AFLC's Configuration Management requires that the software be thoroughly tested and verified prior to approval and release. The objective is incremental rather than continual software changes that are optimally allocated to the appropriate hardware or software subsystem. In addition, potential hardware and/or software impacts from a change are identified and considered prior to implementation. This is done so that the system's integrity and supportability is preserved (1:10).

In meeting these AFLC management objectives, the user required responsiveness has not been provided. In AFLC, ECS is the lease understood, most expensive, and least reliable component of an operational weapon system (7:20). The AFLC organization structure for ECS management has no single management focal point. This lack induces fragmented, ineffective, and inefficient ECS management (2:ii). Consequently, there cannot and does not exist a clear responsibility delineation between functions (2:ii). This condition culminates in the current AFLC Configuration Control Boards' role, function, control, and authority directly impacting user required responsiveness (1:18.6). Concerning the actual software maintenance support, AFLC is experiencing difficulties deciding on whether that support should be organic or contractor (2:ii). In addition, software changes released

by AFLC are receiving inadequate documentation and change review (6:40). The inability to capture lessons learned from one ECS weapon system application and transfer that knowledge to another system is experiencing difficulties (1:16). In this instance, required documentation is inadequate or non-existent and if available does not comply with AFR 800-14 (6:13). Also, AFLC is experiencing personnel problems such as: availability, continuity, morale, tenure, and utilization effectiveness (1:15). These conditions are directly attributable to the lack of a definitive HQ AFLC ECS policy; specifically the areas of: configuration management, deficiency reporting, organizations' responsibilities, and human resource management (2:i).

SCOPE

The impetus of this study is directed towards establishing the required relationships that should exist between AFLC and users of weapon systems having ECS. ECS management practices utilized by Tactical Air Command (TAC), Air Force Logistics Command (AFLC), and the National Aeronautical and Space Administration (NASA) will be evaluated in terms of responsiveness and configuration control in order to determine those relationships.

RESEARCH OBJECTIVES

1. Establish the management system requirements for utilization by AFLC in providing responsive and controlled ECS.

2. Establish the organization structure that should exist based on those determined management system requirements.

RESEARCH QUESTIONS

1. What are the current responsiveness and configuration control requirements at TAC, NASA, and AFLC and determine:

   A. What are the deficiencies in each?

   B. What are the benefits in each?

   C. What configuration control and responsiveness tradeoffs have been made?

2. What is the required relationship between AFLC and users?

Chapter II

SOFTWARE MANAGEMENT PRINCIPLES

Software management publications were researched to determine those software management principles that would be important to the management of ECS in terms of responsiveness and configuration control. The principles identified by this research as having significant impact on responsiveness and configuration control are briefly discussed here. These principles constitute the requirements for a management system to be responsive to users and control ECS adequately. A more extensive discourse of the requirements for each of the principles as they relate to responsiveness and configuration control is provided in Appendix A. Both Appendix A and the discussion here address the relationships between a principle identified and responsiveness and configuration control, exclusively. There is no attempt to delineate the total requirements associated with each principle, their development, or their relationship with other principles. The reader is referred to Appendix A if further review of the principles is desired beyond what is provided here.

RESPONSIVENESS

For a support organization, responsiveness is maintaining the management system capability and the implemented support philosophy of making rapid change to ECS that is required and needed in the user environment. The objectives of the support organization are that changes be accomplished in time to meet users' responsiveness requirements and are effective and supportable within its support constraints. The ability to provide responsiveness is directly impacted by the support organization's structure and by its application of its philosophy for providing that support. The required responsiveness is dynamic in terms of change priority assignment, the importance of that change relative to other in-coming or existing actions, and the current and/or future external environment conditions. Responsiveness is detrimentally effected by the corrective action accomplishment time (which is a function of existing documentation, number of changes previously accomplished, personnel and ECS design). In addition, responsiveness is detrimentally effected by centralization of control in a single point manager who authorizes a change's implementation. An ECS management system must consider each of these responsiveness facets in its development if it is to maintain its viability after development.

CONTROL

The ECS control philosophy establishes the basis for effective responsiveness and configuration control of ECS. The objectives are to (1) centralize maintenance activities as much as possible in order to maximize efficiency and economy, (2) assur users' requirements and operations are not impaired by maintenance activities, and (3) establish checks and balances between users' responsiveness requirements and the support organization's control requirements. The commonality of the control philosophy between organizations is fundamental. The extent of control required is that necessary to assure that ECS's integrity, supportability, operability, and currency is maintained. All aspects of the control philosophy's implementation necessitate the involvement of users of ECS. The control must extend to all changes, whether to requirement or code, whether complex or simple. In order to avoid duplication of effort and conflicting authorizations, the control over ECS should be focused in a single point with all authorizations emanating from that single point. Management system activities required to assure control is maintained but which are not involved directly in the resolution activity should be done in parallel and not sequentially. When tradeoffs are required between responsiveness and control, definite governing procedures must be concurred in by the users and the support organization. In order to assure that ECS control is being maintained

and that that control is not adversely affecting responsiveness, specific timeline standards must be maintained for all control activities and appropriate actions must be taken to modify those activities when evaluation indicates standards are being exceeded. All ECS management systems must address each of these facets of control if they are to be responsive and provide adequate control.

COMMUNICATION

Communication is critical between users and the organization providing ECS support. The closer the interface between users and the support organization, the more effective is the responsiveness and control of the management system. Direct interfaces are required between users and support personnel in order to assure the most effective, timely and continuous support. Emphasis must be on real time communication between these individuals. This means that there should exist minimal management layering, minimal in-house coordination, and direct real-time communication links between the support organization and the users. Due to this make-or-break nature of communication between users and the support organization, communication is a critical element and as such should be reflected in the management system's development. Any cutoff or breakdown of communication seriously effects and undermines the responsiveness and control effectiveness of the management system.

MANAGEMENT

The key functions in ECS management are to Assure (1) that software changes are optimally allocated to the appropriate system, (2) that effective maintenance of the total weapon system is performed, (3) that potential corollary impacts from changes to hardware and software are identified and considered before implementation, and (4) that the weapon system's integrity and operability is maintained. These functions require that all organizations involved with ECS support have their responsibilities clearly and specifically delineated. This includes their internal departments. A formal structure is required with specific identification of contact points with authority and coordination responsibility for the ECS. Relationships must be expressly identified and detailed. Any diffusion of responsibility, conflicts, or responsibility encroachment adversely effects the ability of the ECS to be supported with the required responsiveness and configuration control.

DESIGN

Software design in terms of languages utilized, program complexity, and program structure directly effects responsiveness and configuration control. The greater the complexity and the more intricate the structure, the greater the time required to perform corrective action and the risk that that corrective action performed was not correct. A

management system that does not give consideration to the design of the program to be managed but specifies management system requirements without regard to the program managed will adversely effect responsiveness and configuration control as well as operability, maintainability, and integrity.

PLANNING

The lack of planning as generated from the implementation of the support philosophy is a dominant cause of problems in ECS control and failures to meet responsiveness requirements. Planning is the implementation of the control philosophy by which the support organization provides responsive and controlled software changes to the users. An effective ECS management system must have effective planning for individual changes and changes as a whole in order to provide the responsiveness and control required.

DOCUMENTATION

The extent and level of documentation required in an ECS acquisition is hard to evaluate and determine since shortcomings in the procured documentation are not apparent until a need exists. The fact that documentation directly effects a support organization's ability to perform corrective action necessitates that standards and minimum documentation requirements be established. In terms of maintenance of software, as maintenance is performed, the

difficulty of performing additional maintenance rises exponentially. This is because of the inadequate documentation of these maintenance activities. All maintenance activities must be thoroughly documented and controlled. Lack of this control adversely effects responsiveness and the configuration baseline can be totally lost. Any software management system must have minimum documentation requirements. These requirements are developed jointly by the support organization and the acquisition organization. A detailed analysis of documentation requirements is not included in this effort.

REQUIREMENTS

One of the most important aspects to effective response-oriented support organizations is ECS requirements definition. ECS requirements generation and definition are dependent on the user and as such require the total involvement of the user. Separation of the users from the development of requirements or the implementation of requirements invites misconception and erroneous interpretation of ECS requirements. This separation will consequently impact redponsiveness and configuration control as the released ECS will not meet operational requirements and will require delays for reprogramming and restructuring. A management system addressing responsiveness and configuration control must assure the integration of users and the support organization in the requirements development and their implementation.

USER

The user is that organization that has the operational needs from which the ECS requirements were developed. Only the user has the full operational knowledge of how the ECS will be employed. ECS that is maintained (1) with only average input from or understanding and support of users or (2) by those with whom the user disagrees philosophically or management wise has a usage failure probability rate that rises geometrically with lessening user support and participation. The user is critical to all aspects of the ECS management system if that system is to be responsive and maintain effective configuration control of viable programs. No ECS support effort can be initiated and accomplished successfully without user involvement and commitment to the ECS requirements, its support philosophy, and its management system. Responsiveness and configuration control cannot be accomplished wihout the initimate support, involvement, and participation of users in the management system.

TEST

Testing verifies the operability, compatibility, and integrity of the software to be released. However, there exists no theoretical or practical way to prove that software tested is absolutely correct. Testing of changes to software continues to the extent necessary to assure that

the requirements are met and that no adverse effects result from a change. The time required for testing should not adversely effect responsiveness.

EXECUTIVE STEERING COMMITTEE

This committee's responsibility is to determine the management system philosophy for support organizations. It specifies by its philosophy the management concept, the organization structure, and responsiveness and control guidelines for support organizations. This committee assures that the support provided is consonant with its philosophy and guidelines. Visible evidences of an Executive Steering Committee that is unwilling or unable to perform these functions are communication problems with users, change priority problems, and management layering within support organizations. The presence of these results in control and responsiveness being adversely effected. The Executive Steering Committee is identified in the Air Force environment as a Major Command Headquarters operation.

PERSONNEL

A determining factor in where to locate the single point of control for ECS is personnel. The personnel factors of availability, continuity, capability, experience and orientation are the determining factors as to which organization

should be the single point of control. The organization that can satisfy these factors best is the organization which should be the single point of control.

Chapter III

MANAGEMENT SYSTEMS ANALYSIS

Management systems currently exist which were developed to provide the appropriate degree of responsiveness and configuration control for Embedded Computer Software. Figure Two is a typical management system that provides the appropriate degree of responsiveness and configuration control for ECS. In this context, the objectives of this analysis will be the determination of (1) those management system functions and requirements that impact responsiveness but which are not needed by either responsiveness or control considerations, (2) those management system functions and requirements that are directly attributable to a particular management philosophy, and (3) those management system functions and requirements that are due to control and responsiveness considerations.

Research Design

Three separate and distinct management systems have been selected for evaluation in order to determine the management system requirements needed in providing responsive and controlled ECS. The National Aeronautics and Space Administration's management system for the Space Shuttle's Mass Memory software utilizes a system that attempts to maximize control

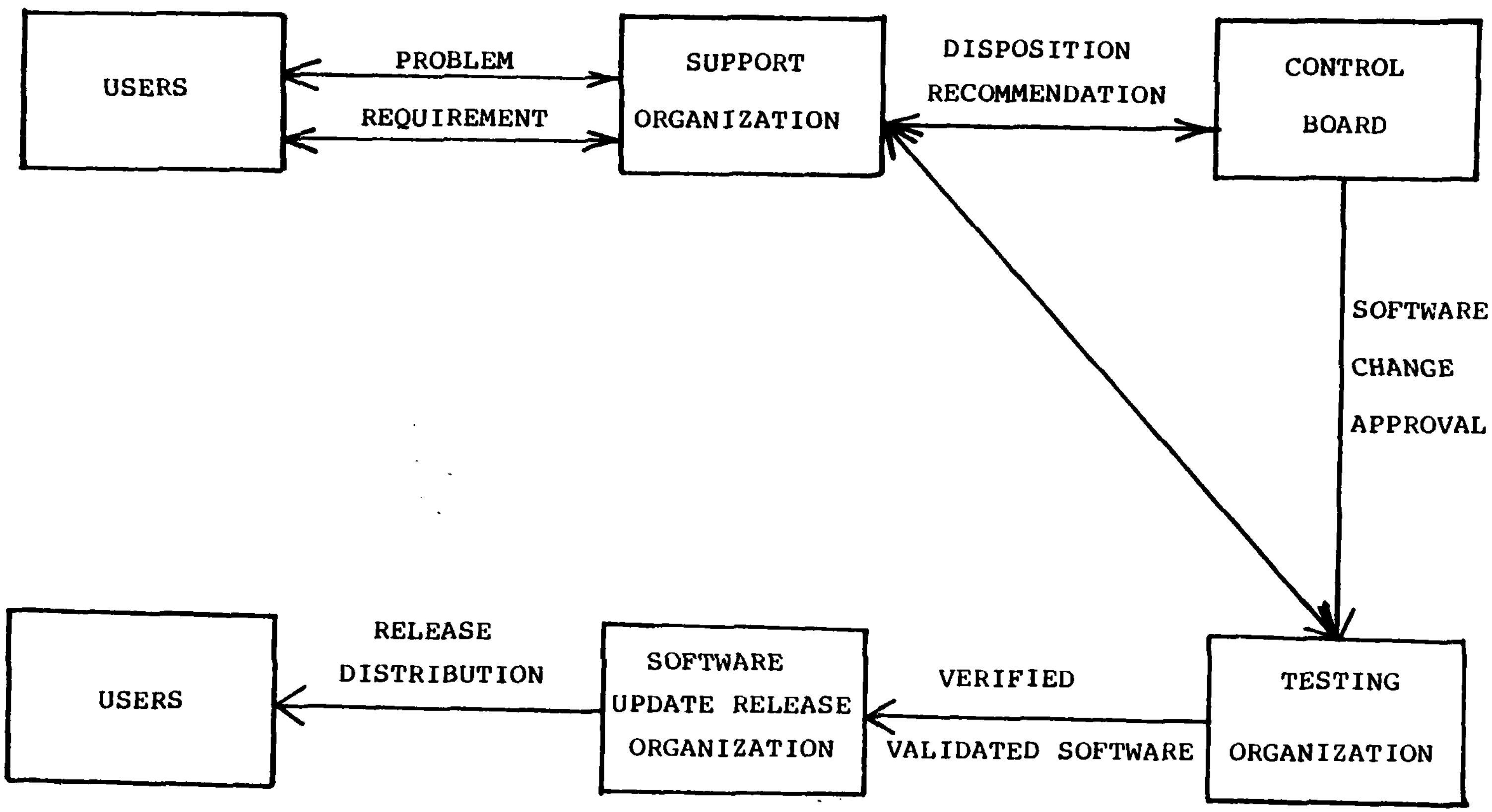

Figure 2

EMBEDDED COMPUTER SOFTWARE INFORMATION FLOW

and responsiveness by means of (1) minimizing time delays due any cause other than corrective action on the software, (2) completing testing concurrently with utilization, and (3) focusing baseline and control in a central point. The Tactical Air Command, United States Air Force Europe, and Pacific Air Force, utilizes a management system that attempts to maximize control and responsiveness by means of (1) minimizing corrective action time, (2) maximizing interface validation and testing, and (3) focusing baseline control in a single focal point. The third subject, Warner Robbins Air Logistics Center, operates under the Headquarters Air Force Logistics Command regulations that dictate timely, efficient, and effective logistics support that is cost effective, mission sustaining, and efficient. Although each of these organizations vary in their particular management system, all have as common goals the maximizing of responsiveness and configuration control of ECS. The composition of each organization's management system was determined by utilizing a structured interview questionnaire (Appendix C) and the appropriate organization's management system documentation.

The structured interview questionnaire was selected because this technique assured all areas of interest were investigated and allowed intense investigation of areas of interest as conditions warranted. This technique coupled with the organization's documentation provided a more realistic insight to the actual formation of requirements,

procedures, standards, and practices in a subject organization. It also provides an opportunity to explore each aspect of a management principle necessary to assure responsiveness and configuration control.

The questionnaire was developed by reviewing each principle that was identified in Chapter II. Within each principle, those factors that were significant or were indicated as being of primary concern to the successful accomplishment of that principle's relationship to responsiveness or configuration control were detailed as a question. The intent was not to restrict information but to enhance the transfer of information between researcher and interview subject. The questions are general in order to provide an atmosphere conducive to the determination of the actual operation of a subject organization's management system and its responsiveness and control requirements. The emphasis in question formation was on the capture of the total intent of the applicable requirements.

Management Systems Simulation

The subject organizations' management system was simulated utilizing the computer program techniques of Q-GERT (see Appendix D). The effort was to establish the various elapse times for each organization's functions to response to a TRW Command and Control program with a known 200 errors in 4400 instructions. Each node and activity in the simulation

corresponds directly to a documented function in the appropriate organization's regulations, requirements, or operating instructions. The elapsed times between functions are purely hypothetical and are not intended to be the basis for evaluating the performance of a specific function. The times are based on actual timeline requirements in the management system. Each model is a reflection of those activities and functions that are actual elements of the respective management systems. The absolute probabilities and routine times determined and utilized are not necessarily accurate. However, the times determined are valid as a basis for comparing management systems. Changing probabilities and routing times to reflect actuals (currently not available) would not appreciably benefit the analysis because:

1. The analysis of a specific function and its performance is limited to the relative impact experienced by the management system from that function.

2. The differences between the management system of interest, the AFLC management system and the other management systems is of sufficient magnitude that "fine-tooth" refining would not contribute appreciably to the analysis.

Certain assumptions concerning the interarrival rate of changes and their routing, activity time, and resolution time were made. These assumptions are identical in all three models.

For interarrival rate of changes, the assumption is that the rate will follow the Mean Time to Failure (MTTF) equation derived from the Shooman exponential reliability equation which is:

$$MTTF = 1/(C((E/I)-e(t)))$$

This equation was selected based on an evaluation by the Rome Air Development Center (RADC) of this equation to reliably predict failures. In this equation, the variable was set at one. This variable is the proportionality constant derived from the amount of testing accomplished prior to the initiation of corrective action for current changes. The variable E is the number of errors currently existing in the program. This variable was set at 200 errors in accordance with the program under test. The variable I which is the total number of instructions in the program in the experiment was set at 4400. The variable function e(t) is the quantity of errors corrected during some elapsed time t. The variable e(t) was determined at the function in the management system where corrective action was actually initiated and not just reported or processed.

Change routing in each model was based on the following criteria:

1. All routes were given an equal probability unless a specific route had been identified during interviews as receiving negligible activity.

2. Changes were routed so that all possible paths would be utilized.

3. Approval action by the various control boards was favored.

4. The elapsed time for a particular activity was described in activity by the applicable organization's documentation.

Corrective Action Time (Isolate, Fix and Document times) of the various activities is based on the work of Goel and Ukmoto for RADC. Based on their research of improper maintenance efforts, which was theoretically substantiated by Captain Sukert of RADC, the following equations were selected:

$$ET = (1/p) \left(\sum_{J=N_o+1}^{E} 1/(\lambda J)\right)$$

$$VAR(ET) = 1/p^2 \left(\sum_{J=N_o+1}^{E} 1/(\lambda J)\right)^2$$

The variable p in the equation is the probability that proper corrective action was accomplished on the change processed. This variable is obtainable from Janson's structural, documentation, integrity, and complexity equation but for these models was set at .9. The variable   is the failure occurrence rate and is the inverse of the Shooman Equation previously discussed. The variable N_o is the number of errors remaining uncorrected at some time t. The variable N_o and e(t) (from the Shooman exponential reliability equation) are directly related and are determined at the same instant. The

variable E is the same as in the Shooman equation. The variable ET is the expected time to perform the corrective action for ($E-N_O$) errors by personnel who are 90% capable of performing the activity properly when those errors are occurring at a λ rate. The variable VAR(ET) is the variance associated with this expected time. This particular set of equations was selected because the corrective action time is a function of the number of changes corrected and of the point in the management system that that action is taken. Utilization of these equations was as follows:

1. For change diagnosis and/or problem isolation, the value determined for ET was used.

2. For changes requiring a documentation change only, the value determined for ET was used.

3. For change implementation, a Gamma distribution was used with the mean equal to ET and the standard deviation equal to $\sqrt{VAR(ET)}$.

Simulation Results

Tables 1, 2, and 3 are listings of the results from the simulation of the three management systems under investigation. The title of a particular entry is related to a particular function in the applicable management system. The time entries are related to the hours elapsed in the simulation from the initial receipt of a change to the initation of that function's activity. The two columns of means and standard deviations are related to whether or not a particular

TABLE 1

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
SIMULATION RESULTS

	Mean	Std. Dev.	Mean	Std. Dev.
1 IBM Action Time	31.7289	1.3689		
Quick-Look Report			42.2419	.2611
2 Requirement Change				
Evaluation	744.4682	552.2257		
Level III CCB	2631.8967	405.8475		
Appeal OASCB	2634.6167	589.3351		
No Appeal			2401.8561	487.9230
OASCB Wait	2967.1115	366.6585		
3 Emergency Change				
OASCB	57.3015	25.4288		
Approval			56.6199	14.3172
Disapprove	94.2372	49.5666		
4 T&O Board	50.7834	5.1155		
Test/Facility Unique Change				
OASCB	83.1415	12.8275		
5 Permanent Change				
Discrepancy Report	47.7059	12.5192		
Fix Discrepancy	400.4092	436.1064		
Waiver	228.2155	68.3481		
6 OASCB	638.7953	221.5906		
7 Mass Memory Release Coordination	616.6719	177.0161		
Release Build	783.6197	177.6570		
Software Release	796.2309	177.0275		
8 User			807.9521	177.1572

TABLE 2

TACTICAL AIR FORCES
SIMULATION RESULTS

	Mean	Std. Dev.	Mean	Std. Dev.
1 CPCSB				
No Action Required			47.8850	4.4210
Implement Change - No Impact	61.7845	9.3481		
Change Assessment	58.3911	8.2456		
3 TAF CCB Emergency	71.9910	17.3139		
Emergency Implement			130.4472	27.4238
4 TAFIG	54.3917	8.2335		
Evaluation	100.9940	20.7900		
AFLC SM/IM Cood.	197.3004	17.7711		
6 TAF CCB	323.7698	52.7037		
Disapprove			354.9242	60.0761
2 TAF Baseline Impact				
Downgrade Class II	363.9601	101.3319		
Joint Stnd Bd	352.9906	106.9564		
Stnd Impact	364.8724	104.8570		
Disapprove			401.6684	143.2126
Higher HQ Action			531.0835	102.7695
Approved Change-Test	587.9209	225.5037		
5 TAF Baseline Impact Assessed				
Implement	323.5193	35.7096		
Joint Test Required				
Joint Test Force	472.0060	97.2893		
Test Failure	659.0576	164.5707		
Test Success	762.7238	94.4880		
No Joint Test	644.3791	97.3060		
Testing				
Test Rqmts	671.2421	212.4967		
Test Evaluation	1060.3709	237.3199		
7 Release Version	869.5811	188.7473		
8 User			890.1693	188.6757

TABLE 3

WARNER ROBINS LOGISTICS CENTER
SIMULATION RESULTS

	Mean	Std. Dev.	Mean	Std. Dev.
1 2 Initial Processing				
Arrival	.6137	.1721		
Reroute CAT I			2.0541	1.1116
Reroute CAT II			13.6714	.8400
SM/IM MIP Clerk	16.9969	2.8893		
Technician Review	18.0650	2.9382		
CPSP	29.6874	2.6329		
CAT I Response			24.6413	.3719
CAT II Response			104.7149	4.7470
MMECT Review	41.4418	2.1010		
2 4 Computer Program Control Sub-Board				
Transfer Responsibility			1031.7495	281.8839
Disapprove			1823.0839	328.5522
Approve	1123.3936	55.7468		
2 6 Configuration Control Board				
Disapprove			1948.4690	303.8037
Approve	2040.6511	37.0488		
Funding Constraint				
HQ AFLC Action				
Disapprove			1457.3656	424.3656
5 In-House Determination	837.5193	202.1883		
Contractor			2986.8867	68.3569
Inhouse				
Fix/Change	2291.3860	358.4516		
Pelim Design	2537.0158	280.1771		
Detail Design	2574.2568	113.4502		
Code/Test	2878.5033	90.5891		
Validate	2964.5467	171.7589		
Kit Proof	3114.2665	361.6544		
7 Computer Program Control Sub-Board	3227.3776	305.8933		
8 User			3156.4887	242.3773

3 All Emergencies Downgraded to Routine, 1

function's activity was a terminal step or whether another activity followed. If a terminal step, the times determined were entered in the third and fourth columns. If another function followed, the times determined were entered in the first and second columns. The circled numbers are indicators of similar functions in the various management systems.

Based on simulated elapsed response time, the Tactical Air Force management system is the best management system for ECS. This is because of the Tactical Air Force's management system's ability to address both requirement changes and design changes in less time than in the other two systems. While the NASA response time is better for design changes (807 elapsed hours), the impact of a required change on this system is significant (2967 elapsed hours). Of the three management systems, the Warner Robins Air Logistics Center system is the most unresponsive (3156 elapsed time regardless of type change). The impact of a particular organization's management philosophy is also quite apparent. In the Tactical environment, 64% of the total elapsed time in accomplishing a change is in testing. This is consistent with the Tactical environment's concept of assuring via estensive testing the interoperability and compatibility of of interfacing systems. In the NASA environment, 80% of the total elapsed time in accomplishing a change is prior to the OASCB. This is consistent with the OASCB management philosophy of assuring the correct content and maintainability of software released to a user. The major elapsed time

consumers in the NASA environment are those organizations which have been delegated responsibility to verify, maintain, and correct their subprograms within approved requirements. In the Warner Robins environment, 65% of the total elapsed time is expended prior to the CCB. The impact of this condition on responsiveness is significant because in both the Tactical and NASA environment the time spent prior to the CCB is in corrective action accomplishment. In the Warner Robins case, this CCB authorization is to commence the work that both of these other organizations have completed by this point. The processing time in the Warner Robins management system subsequent to CCB approval (1116 elapsed hours) compares favorably with that of the other two management systems (800 elapsed hours) in performing corrective action.

The greater elapse time required in the AFLC environment in performing corrective action is partially attributable to its interpretation of change blocking. The AFLC interpretation is that sufficient quantities of changes be held in abeyance for three months and corrective action performed concurrently on these changes. In NASA and the Tactical environments, change blocking is a function of individual change's priority. In the NASA and Tactical environments, the time expended in corrective action was 350 and 62 elapsed hours respectively. The greater NASA time was due to management layering between the initial report and the corrective action initiation. In the Warner Robins environment, the elapsed time was 1116 hours. This difference is attributable

to its management layering and its change blocking concept. These results are directly in keeping with the equations utilized which stipulate that the corrective action time requirement increase exponentially as management layers increase, as the location of the corrective action is physically removed from the location of initial reporting of a problem or change requirement, and as the quantity of changes corrected increases. The validity of this simulation statistics is confirmed by the increasing need by the Air Logistics Centers providing ECS support to expand their timelines for software maintenance releases.

The rapid turnaround times provided by the simulation in both the NASA and the Tactical environments substantiate the importance of having the participation of the users in the processing of a change. The ability in the Tactical environment to accomplish corrective action at an early time (58 elapsed hours) is attributable to the location of users in their Computer Program Control Sub-boards. In the NASA environment, the ability to quickly identify the required action for a particular change (31 elapsed hours) is attributable to the location of personnel at the users facility. In the Warner Robins environment, the users are not involved. This lack contributes to the elapsed corrective action time requirement being 1123 hours.

Management Systems Simulation

Conclusions

Based on the similarity of activities, the needed functions in a management system are:

(1) a group comprised of users, System Management personnel, and Engineering personnel to evaluate the required responsiveness for a change,

(2) a control board to determine the required action on the change,

(3) a group to perform the required action, and

(4) a control board to authorize release of corrected software.

All other findings outside these four are extraneous and impact responsiveness. In the Tactical and NASA environments these functions are present with minimal management layering, direct real time interface communication, and minimal change priority problems. The same is not true in AFLC. For the AFLC management system these needed functions are found in the existing Computer Program Screening Panel, the Computer Program Control Sub-board, the MMEC function, and the ALC's CCB. All other functions outside these basic functions should have either negligible impact on the management system or perform their activities in parallel with these functions.

The blocking concept as presently utilized in AFLC and simulated in the model is adversely affecting the ability of this management system to be responsive to change action

requirements. However, in order to reduce the magnitude of the impact of this concept all three aspects of this problem, that is management layering, direct interface capability, and priority change blocking, must be changed.

Since the amount of time expended by Warner Robins prior to CCB action is effort that will have to be duplicated subsequent to the CCB approval of a change, all actions associated with this time should be eliminated. The numerous functions during this time only complicate the corrective action process by extending processing time. These functions' activities must be performed, if at all, without an adverse impact on the management system. In particular:

1. The function of receiving change requirement reports in the management system is not required. This function only adds time to the processing and the review it performs must be accomplished subsequently by other functions. In addition to this function, the review to determine the responsible System Manager function does not contribute to the resolution of the corrective action required. The point where identification of the required effort for a change is in the Materiel Management Engineering Division (MMEC). After this review, a determination is made of the required corrective action. The Computer Program Screening Panel function, which is currently structured prior to the MMEC function, should be accomplished subsequent to the MMEC function in order that a viable disposition recommendation can be made. Placing the Computer Probram Screening Panel

activity subsequent to the MMEC review would eliminate the 1123 non-resolution processing hours in the AFLC management system. This change is in harmony with reducing management layers and providing direct interface capability by locating the activity for resolving a required corrective action as close as possible to the initial reporting of the problem.

2. Composition of the Computer Program Screening Panel must be expanded to include the users. This enhances the direct interface capability with those to whom support is being provided. The corrective action elapsed time can also be benefitted in terms of determining the extent of testing required, the needed corrective action, the users priority for the change, and the specific change requirements. The impact of this participation would decrease processing, testing, and corrective action time.

3. Based on the determination by the Computer Program Screening Panel, a viable recommendation can be made to the Computer Program Control Sub-board on each change. The objective of this board must be to determine (1) whether contractor action is required to correct the problem or an in-house effort will suffice and (2) whether the required funding of the change is within the Air Logistic Center's authorization. Based on these interrelated determinations, the board can authorize action to be initiated as an in-house effort, or as a requirement determination effort prior to contractor support, or obtain funding from HQ AFLC after

approval by its CCB. Specific testing requirements should be determined at the Computer Program Screening Panel. Tradeoffs between testing performed by the users subsequent to release and that required by AFLC should be negotiated with the objective of minimizing testing duplication. In the NASA environment, only required testing is accomplished and that is determined in conjunction with the users. The benefits of this testing determination action to the Air Logistics Center would be a reduction in change processing time.

For those changes involving new requirements, there does exist considerable time delay associated with new requirement support regardless of the management system. In the NASA environment, considerable time (2967 elapsed hours) was expended in this effort. This is due to the ECS requirement generation coordination requirements of the management system. In the Tactical environment, there was no delay. This is due to the fact that the development of software in the Tactical environment is an in-house effort and as such would not involve the delays associated with obtaining contractual support. However, the NASA management system is a substantial improvement over the AFLC capability due to its minimal management layering and direct interface with users.

The function of the Air Logistics Center's CCB should be authorization of (1) contractor performed work, (2) all software releases, and (3) all changes exceeding funding

constraints which require HQ AFLC approval. This authorization should be provided when the requirements for the contractor have been specifically delineated and agreed to by users, just prior to software release, or prior to seeking funding approval dictated by the appropriate stiuation.

It can be concluded from the philosophy policy of the Warner Robins management system its structure and implementation that a basic reorientation in this management implementation system is required. The implementation of its management philosophy has to be committed to the mission capability requirements of ECS users and to assuring that software released is in compliance with those requirements.

Chapter IV

SOFTWARE MANAGEMENT PRINCIPLES RELATIONSHIPS DETERMINATION AND MANAGEMENT SYSTEM IMPACT ASSESSMENT

The application of the software management principles stated in Chapter II in an ECS management system, dictate the responsiveness and control to be experienced by that management system. The purpose here is to (1) determine the relationship between software management principles which affect responsiveness and configuration control, (2) determine the required applications of these principles to an ECS management system, and (3) identify those principles by that particular management system function. These determinations will be based on a model management system that is comprised of the four basic management system functions exclusively.

Determination Analysis Technique

The sources researched previously for the software management principles were utilized to determine causal relationships between individual software management principles. The purpose was to determine those factors that constituted a principle. This was accomplished by reviewing each source and identifying specified causal relationships. It was

assumed that a specified causal relationship cited by a source for an applied principle was valid. Relative weights were determined for each factor of an applied principle by assigneing a value of one to each causal relationship applicable to that principle, aggregating the identified causal relationships by factor, summing the aggregates, and then dividing each aggregate by this sum. Relative weights so derived indicate the relative impact of that particular factor on the applied software management principle in question. In order to reduce bias from any one source, each source's causal relationships and their corresponding relative weights for a particular applied software management principle provided by one source were given the same consideration as those provided by all other sources. Factors and their corresponding relative weights for a particular applied software management principle from one source had an equal contribution to the resulting composite relative weight for an applied principle as those from other sources. These relative weights for an applied software management principle were determined utilizing a computer Fortran program (Appendix E). Table 4 is a listing of those composite relative weights so derived. The "I" in any relative weight block indicates an initial factor in the management system. An initial factors, or exogenous variables, is the standard operating procedures of a management system. These initial factor's compliance with its software management principles

TABLE 4: FACTOR COEFFICIENTS

Factor \ Principle	Maintainability	Executive Steering Committee	Plan	Change Rate	Control	Personnel	Test	Management	Design	Requirements	Communication	Documentation	User
Maintainability (Responsiveness)	--	.02[I]	--	--	--	--	--	--	--	.04	--	.05	--
Executive Steering Committee	--	.63[I]	.70	--	.02	--	.37	.04	--	.24	--	--	.02
Plan	.12	.14[I]	--	.14	.74	--	.08	--	--	--	.01	--	--
Change Rate	.02[I]	--	--	--	--	.11[I]	.01[I]	--	.05[I]	--	--	--	.16[I]
Control	.04	.19[I]	--	--	--	--	.18	--	--	.29	.01	.09	--
Personnel	.20	--	--	--	.06[I]	--	--	--	.14	--	.02	--	--
Test	--	.01[I]	.14[I]	.48	.11[I]	.04[I]	.10[I]	.60[I]	--	--	.16	--	--
Management	--	--	--	--	--	.38[I]	.08	--	--	.43[I]	--	--	.10[I]
Design	.34[I]	--	--	.28	--	--	--	--	.47[I]	--	--	.63	.02[I]
Requirement	--	.01[I]	--	.09	.06[I]	--	.11	.21	.20	--	--	.03	--
Communication	.08[I]	--	--	--	--	.30[I]	--	--	.14[I]	--	--	--	.02[I]
Documentation	.19[I]	--	.10[I]	.01	.01[I]	.04[I]	--	.03	--	--	.15	.20[I]	.12[I]
User	.01	--	.06	--	--	.13	.07	.12	--	--	.65	--	.56[I]

requirements vary and can be utilized to determine the degree of compliance an applied principle has in the management system to the software management principles. This compliance is reflected in the management system's dynamics. Since there does exist an extensive interrelationship between the various applied software management principles, any perturbation of one applied principle will have an affect on the others. The relative weights derived are not absolute but are a linear representation of the actual relationships. If error does exist, it will be in the fact that a factor behaves exponentially rather than linearly. The exponential nature of a factor stated by one source was ruled out if it was not substantiated by any of the other sources.

The modeling simulation techniques of Dynamo were utilized to determine the required application of software management principles to an ECS management system. This was performed by developing equations relating the four basic functions in a management system as levels of the management organization and utilizing as levels of activity for these functions the rates utilized in the Q-GERT simulation (Appendix D) management system. The relationship of the various applied software management principles to the management system was in the form of information flow into the appropriate function. This is because an applied principle does not have a specific level of activity associated with it but it does affect the degree of activity of a management system function.

Those applied software management principles affecting a particular management system function were identified from the responsibilities of the applicable function as detailed in the AFLC, NASA, and Tactical management system documentation. Equations specifying the relationships between software management factors and applied software principles were based on Table 3. The interface between the management system and the appropriate applied software management principles was accomplished by utilizing a combining step. This combining step integrated the applied software management principles involved with a particular function. The combining step gave equal weight to each involved applied principle. This equal weighting of applied software management principles for each function was based on the assumption that each software management principle was required. No applied principle was identified as needing additional emphasis in the management system documentation. The Dynamo simulation program is listed in Appendix F.

Initial Factors Management System Impacts

The software management principles identified as exogeneous variables (initial factors) were assigned in Table 4 several values to simulate varying degrees of compliance with the requirements of that software management principle. Accordingly, full compliance was one, half was .5, and no compliance was .1. During any simulation run only one initial

factor varied while the remainder were held constant at full compliance. By this method, isolation of the effects on the responsiveness and control of the management system (in terms of hours required to make a change) due to an initial factor could be identified. Table 5 is a listing of those results of these simulations for each exogeneous variable. For each exogeneous variable, there are two entries for each function of the management system. The first (.5) specifies the relative effect of the variable of interest on the curve describing that particular function's level of activity from that when the factor was at full compliance. The second entry (.1) specifies the relative effect of the variable of interest on the curve describing that particular function's level of activity with respect to that function's level of activity when the variable had a value of .5. Each initial factor impacts applied principles which in turn directly impact responsiveness and configuration control. The reduction in compliance of an initial factor and its resulting impact on the applied principles produces the dynamic nature of the management system modeled.

The only initial factor with an impact on the management system for the Software Engineering's level of activity was Testing. The remainder of the variables indicated no impact regardless of value. For Test, degradation of ECS testing or failure to test ECS would result in a constant increase in the level of activity for the Software Engineering function. The degree of constant increase would be independent

TABLE 5: EXOGENEOUS VARIABLE GROUP LEVEL IMPACT

Software Management Principle	Software Engineering		Screening Panel		Configuration Sub-Board		Correction Action		Configuration Control Board		Release	
	.5	.1	.5	.1	.5	.1	.5	.1	.5	.1	.5	.1
Maintainability	C	C	C	C	C	C	EI	C	EI	C	EI	C
Test	CI	CI	CI	CI	EI	GI	EI	GI	EI	GI	EI	GI
Control	C	C	CI	C	EI	C	EI	C	EI	C	EI	C
Executive Steering Committee	C	C	GD	GD	EI	GD	EI	GI	EI	GI	EI	GI
Plan	C	C	C	C	EI	C	EI	C	EI	C	EI	C
Requirements	C	C	C	C	EI	EI	EI	EI	EI	EI	EI	EI
Responsiveness	C	C	C	C	EI	C	EI	C	EI	C	EI	C
Design	C	C	GD	GD	EI	GD	EI	EI	EI	EI	EI	GD
Communication	C	C	GD	C	EI	C	EI	C	EI	C	EI	C
Documentation	C	C	GD	C	EI	GD	EI	GD	EI	GD	EI	GD
Personnel	C	C	C	C	EI	C	EI	C	EI	C	EI	C
Management	C	C	C	C	EI	GD	EI	EI	EI	EI	EI	EI
User	C	C	GD	C	EI	GD	EI	GD	EI	EI	EI	EI

Key: C - Constant
CI - Constant Increase
GD - Geometric Decrease
EI - Exponential Increase
GI - Geometric Increase

of other degradations in Testing. Each degradation in the Testing principles describes an individual effect on the management system. Since it is a constant increase over any value of degradation of the Testing principle, there is no exponential growth in the level of activity for the Software Engineering function. If a degradation of Testing was accomplished for some management reason, the impact of that degradation on the Software Engineering function would not be sufficient to warrant the precluding of that management action.

For the Screening Panel level of activity, Test, Control, Executive Steering Committee, Design, Communication, Documentation, and User had an effect on the management system. The effect of Test on the management system was the same as in the Software Engineering stage and the same conclusions there are valid here. For Control, the further degradation of this variable to .1 resulted in no further change from the level of activity described when the variable was at .5. This would indicate that there is a critical point in the Control initial factor that affects the Screening Panel but subsequent to that point that no further impact is experienced. Degradation of the Control initial factor is not precluded based solely on its impact on the Screening Panel stage. The variables of Executive Steering Committee and Design both exhibited the same characteristics. The geometric decreases affect of these initial factors on the

management system indicate that degradations of these two variables would enhance the level of activity for the Screening Panel. Any enhancement in the level of activity by these variables at an initial stage of the management system will have an exponential increase impact on a subsequent stage of the management system. This is realized as an exponential impact on the Corrective Action stage of the management system. Accordingly, any degradation of these two initial factors which would be beneficial to the Screening Panel would be severly detrimental to the Corrective Action stage and should not occur. The variables of Communication, Documentation, and User all exhibit the same impact on the management system. The impact of these initial factors' degradation on the management system is similar to that of the Executive Steering Committee. Any degradation in these initial factors benefits the Screening Panel at the expense of the Corrective Action function. Degradation of the initial factors of Executive Steering Committee, Design, Communication, Documentation, and User should be avoided due to the exponential impact experienced by the management system subsequent to the Screening Panel stage.

There is only one initial factor that does not affect the Configuration Sub-board, Maintainability. All of the remainder exhibit an exponential increase in the level of activity for the Configuration Sub-board. A variable that exhibited a geometric decrease in the level of activity from

an initial exponential increase would support the determination that the variables exhibiting this characteristic are asymptotic. Such variables are: Executive Steering Committee, Design, Documentation, Management, and User. Although degradation of these variables is bounded by the asymptote, any degradation of these variables results in conditions in the later stages of the management system that are detrimental to the system. The initial factors of Plan, Control, Responsiveness, Communication, and Personnel all exhibited an exponential increase that remained constant with continued degradation of the variable. This indicates that there is a critical point in the degradation of these variables beyond which no further impact on the Configuration Sub-board will be experienced. For the initial factors of Test and Requirements, no degradation of these management principles is practical. Both resulted in continued exponential or geometric increases in the level of activity for the Configuration Sub-board for subsequent degradations. Based on the impact of these variables, Test and Requirements, to the Configuration Sub-board, both must not be allowed to deviate unmonitored.

All of the initial factors resulted in an exponential growth in the level of activity for Corrective Action. The principles of Test, Executive Steering Committee, Requirements, Design, and Management can experience no degradation due to the impact that further degradations have in terms of continual exponential or geometric increase in the level of

activity for Corrective Action. The principles of Maintainability, Control, Plan, Responsiveness, Communication, and Personnel indicate a constant exponential increase regardless of the degradation of the variable. This would indicate that there exists a value at which further degradation of the variable has no impact. The initial factor of Documentation has an asymptotic relationship to Corrective Action's level of activity.

The initial factors of Test, Executive Steering Committee, Requirements, Design, Management and User have an exponential increase relationship with the Configuration Control Board's level of activity. The remainder of the software management principles indicate an exponential increase that does not vary with further degradation of the variable.

For Software Release, the variable of Test, Executive Steering Committee, Requirements, Management, and User are critical and no degradation of these variables can be experienced without increasing the exponential increase in this level of activity. Design and Documentation exhibit an asymptotic relationship to Software Release. The remainder of the principles remained constant after some critical value had been passed in the degradation of the principle.

Management System Function Critical Exogenous Variables

Based on the impact to the management system of an exponential growth in the level of activity for that function due the degraded responsiveness and control ability of the management system, a determination can be made as to when compliance with an initial factor must be assured in order to avoid detrimental impacts to responsiveness and control from management system function. During the Screening Panel function the emphasis should be on the requirements of the Executive Steering Committee, Design, Communiation, Documentation, and User. During the Configuration Sub-board function, the primary initial factors are Test and Requirements. In addition, the initial factors of Plan, Personnel, Responsiveness, and Control require verification. At the Corrective Action function, the initial factors of Management and Maintainability require attention. These assignments signify that that is where attention to a particular initial factor becomes critical for the management system. Table 6 is a ranking of the software management principles based on the magnitude of the impact experienced by the management system when the appropriate initial factor had a value of .5. These rankings coincide with the management system determinations of when an initial factor becomes critical. Table 6 provides a priority guide as to which initial factors should receive attention at a particular management system stage.

TABLE 6: RELATIVE RANK OF EXOGENOUS VARIABLES

Principle	Software Engineer	Screening Panel	Sub-Board	Corrective Action	CCB	Release
Maintainability	0	0	0	1	2	13
Test	0	5	2	6	8	6
Control	0	6	4	4	6	4
Executive Steering Comm	0	2	9	11	13	12
Plan	0	0	3	3	5	3
Requirements	0	0	1	2	3	1
Responsiveness	0	0	3	5	7	5
Design	0	3	5	10	12	9
Communication	0	4	6	7	9	7
Documentation	0	4	8	8	10	8
Personnel	0	0	7	1	4	2
Management	0	0	10	12	1	11
User	0	1	8	9	11	10

Interpretation of Software Management Principles Critical to Management System Function

The meaning of an initial factor's impact on the management system can be interpreted and is based on the requirements of the initial factor's software management principle, those applied principles it affects, and the initial conditions of the model. Each software management principle will be reviewed with the objective of identifying those requirements of a principle that contributed to that principle becoming a critical management concern.

The User principle is the most critical concern to the Screening Panel function of the management system. Based on the initial conditions of all exogenous variables being in full compliance, the factor that is contributing to this concern is the initial User conditions. This can mean that there is only average support input from the Users for the ECS support activity or the users disagree with the support being provided. The resulting impact of the user principle degradation at the Corrective Action function signifies the importance of the Users support and participation in the initial functions of a management system for ECS. User participation and support of the management system is fundamental at this early function of the management system and must continue throughout the remainder of the management system.

The Executive Steering Committee has the second most significant impact on the management system at the Screening Panel. Since all of the initial variables excluding the Committee itself are initialized at full compliance, the determination can be made from the factors of this principle that the cause of the impact is the principle itself. The purpose of the Executive Steering Committee is to provide goals for the support organization, define responsiveness requirements, and assure effective participants communications. When there are problems in this principle, it is identifiable by management layering, communication problems, and no User support. Since both Communication and User were initialized at full compliance, it can be ascertained that the impact experienced by the management system is due to the layering of management between the Screening Panel and the User. In this model there is only one management layer between the user and the Screening Panel, the Software Engineering function. The impact of this one management layer on the management system and its later ramifications on the Corrective Action function highlights the importance of reducing and minimizing various management layers. The interface between the Screening Panel and the Users is critical and as such should have minimal management layers separating them. The one management layer in the model is essential to the Screening Panel's ability to function but

no other layers can be allowed. Even with this required management layer, the emphasis must be on assuring no other layers and no degradation of the management system from this layer.

The Design principle are the concepts utilized in developing the ECS. It is the design requirements and the actual design techniques employed by design personnel in the development effort. The impact to Design are in terms of complexity, readability, and inflexibility of the ECS. These factors have a significant impact on the personnel who will perform the corrective actions. The significance of the impact of Design on the Screening Panel is that as the complexity of the design increases, it affects the ability of the support personnel to interpret what corrective action is required. This in turn causes a delay in the Screening Panel in determining the appropriate action for a change. This complexity of design along with its inflexibility and difficulty in readability will have a significant impact on the Corrective Action function. The Design of the ECS must be kept as simple as possible utilizing structure and design techniques that will reduce complexity of the design. The impact of Design on the management system indicates the necessity of standard Design requirements for ECS in order to reduce the complexity inherent in independent design efforts.

Communication involves the User and the support organization exchanging information as to condition, priorities, requirements, and utility of the ECS. Although the User may be in support of the ECS management system, if his requirements are not being communicated to the support organization, that support is to no purpose. The degradation of Communication to the Screening Panel function highlights the importance of an effective communication link with not only the Users of the ECS but all other organizations providing support or involved with the ECS. A degradation of the Communication principle signifies that the necessary requirements for the ECS are not being conveyed and erroneous or unusable ECS can be provided. It also signifies that the design effort by the support organization is being done independent of the organizations which specify the ECS requirements.

The Documentation principle degradation and its associated impact on the management system illustrated the importance of the support organization being provided the appropriate support documentation. This documentation includes requirements, maintenance, and design documentation. Extensive research has identified what documentation is necessary for a support organization to function effectively. The significance of this simulation was to indicate at what point in the management system that this required initial documentation had a significant impact on the management

system. The Screening Panel is this initial function of the management system and any impact at this point can have only an increasingly exponential impact on the management system.

The Configuration Sub-board is the function at which the Requirements principle became critical. This is understandable since this is the point at where the decision must be made as to the requirements of ECS. Based on this requirements determination, decisions are made as to the priority of the required action, its scheduling requirements, and the appropriate action. These determinations cannot be made independent of the ECS requirements.

The importance of the Test principle to the Configuration Sub-board is in terms of what testing has been done, what is required, and who will perform it. Inadequate testing of ECS has a direct impact on the reliability of the ECS being provided to Users. Whether that testing is accomplished by the support organization or in conjunction with the Users is not stipulated. The emphasis is on a determination of what the requirements for testing are. Based on these determinations, the appropriate decision can be made to assure the appropriate testing is accomplished.

The degradation of the Planning principle means that either the specified palnning for ECS support is not being complied with or that none exists. Since a management system does exist, it can be ascertained that the planning either is of poor quality or does not have long range objectives, or does not address life-cycle costs. This conclusion is

substantiated by the findings of the simulation of the Warner Robins Air Logistics Center's management system. The emphasis in that effort was on compliance with the milestones of the G026 system which were contrary to the Planning principle. The objectives of planning at the Configuration Sub-board are in providing the most efficient and economical course of action for a support organization's activity. This can not be done unless long-range strategic planning for ECS support has been accomplished.

Responsiveness is the result of the culmination of all of the software management principles and is apparent at the Configuration Sub-board. At the Configuration Sub-board, the primary concern is the priority of the actions being reviewed. The loss or replacement of the responsiveness requirements of the support organization indicates that responsiveness is not important. As established by both simulations, the result of the replacement or loss of responsiveness is extension of the corrective action time.

The Control principle's objective is to assure that the support for ECS is responsive and that the correct ECS content and capability is being provided to the ECS users. Those determinations are initially made at the Configuration Sub-board. Degradation of the control function can either be from erroneous updates to the ECS by personnel or from Users taking corrective action as a result of unresponsive support organizations.

The ease of maintenance that is built into ECS initially and subsequently in corrective actions determines the ability to perform corrective action. As maintainability of ECS decreases, the ability of personnel to perform the required corrective action is impaired. As a result of any corrective action, the maintainability of the ECS is affected by the degree to which the corrective action changed and affected the ECS. The desired level of maintainability required to support ECS must be present before and after any corrective action. Maintainability has a significant impact on the management system at the Corrective Action function due to the fundamental nature of that activity.

The Management principle is concerned with the optimal allocation of corrective actions, ECS's integrity, and ECS's operability. These elements are directly affected at the Corrective Action function of a management system. Due to the inherent flexibility of software, tradeoffs can be negotiated on whether or not a certain software change should be accomplished. The main concern in this instance is in what benefits can be derived from the system if the ECS is changed in a way that is sub-optimal without adverse affects. Although the management principle is not as critical as the other principles in the management system, Management does have an exponential impact on the management system.

Management Systems Principles Application Analysis

Each software management principle has a fundamental role in assuring responsiveness and configuration control in the ECS management system. The importance of each principle is tied to the activities of that function in the management system to which it is most directly related. The application of the software management principles in the NASA and in the Tactical management systems directly contribute to the ability of these two organizations to provide responsive support. Conversely, the lack of the software management principles application in the Warner Robins management system directly contributes to the inability of this management system to be responsive. The difference in responsiveness magnitudes is dependent on the adherence to sfotware management principles.

National Aeronautics and Space Administration Space Shuttle Mass Memory Management System

The management philosophy for the Orbiter Avionics Software Control Board (OASCB), the single point of control for the Space Shuttle's Mass Memory software, is directed towards assuring correct configuration of all software within the Orbiter Avionics System, including Mass Memory Units, during all vehicle and test operations. In order to accomplish this

responsibility, the OASCB has defined the procedures and responsibilities used to assure the correct content and maintenance of avionics computer memories and mass memory units tapes.

The responsiveness requirements of maintaining the capability and concern to make rapid changes is accomplished by collocating personnel at the various sites utilizing the software. These collocated groups, IBM Test & Operations (T&O), are given specific tasks to assure that software released to a site is being utilized properly, that known problems and changes are recognized and considered, that work-around procedures that have been previously approved are utilized procedures that have been previously approved are utilized when required, that installation of the software is proper, and that no programming or alterations takes place without prior approval from the OASCB. In addition to providing this utilization support, these collocated groups provide on-site support on a 24-hour basis and monitor all activities involving the software. In the event a new requirement or problem is generated, this group assures the validity of the action, verifies that it is not a unique occurrence, gathers as much relevant data as possible for diagnosis of cause, and reports all actions whether unique or repeatable, problem or requirement to the Test and Operations Board of the impacted subprogram within 24 hours. Most importantly, this group negotiates between the users and its Test and Operations Board the priority of a required

action, its need date, and its relative importance to other actions existing or incoming. This evaluation of priority is accomplished daily with all new and old actions not in work reevaluated for priority. The timeliness requirement agreed to by this process is the deciding factor in the providing of logistics support for a particular action.

In line with its responsibility of assuring that the correct software content is available, the OASCB exercises total control over all software released and its documentation. For those changes accomplished on an emergency basis, approval by the OASCB is mandatory within 24-hours or the change must be removed from the software. Only those changes specifically approved by the OASCB are built into a new tape release and only those tapes expressly approved, via the OASCB release documentation, are released for utilization by users. In order that the OASCB will not impact responsiveness, the OASCB meets on a daily basis with telephone and emergency meetings held on an as-required basis. Since the main purpose of the OASCB is operational software, its management philosophy is common with that of the users. The requirements of software integrity, supportability, operability, and timeliness has been specifically delegated to the responsible development organizations' Test and Operations (T¢O) Board. The T&O Boards are authorized to develop changes compatible with the OASCB approved requirements and cannot release their software until approved and processed by

the OASCB. The emphasis of these T&O Boards is to provide the required software as needed. The OASCB is responsible for assuring interfaces, operability, compatibility, and integrity of software released to users.

The required communication is implemented by integrating all activities with affected organizations as much as possible. The collocated groups are part of a specific Test and Operation Board and as such perform important liason functions as coordinating schedules, assessing priorities, reporting problems and performing release coordination (release) with the users, the Test and Operations Board, and the OASCB release organization. The Test and Operations Boards maintain effective communication with all users and affected organizations by providing membership on their board for representatives from each affected organization. The OASCB release organization, the Mass Memory Release Coordination Team, is that organization that is specifically charged by the OASCB to develop and implement all aspects of logistics support for all software releases and actions. This team involves all members of the OASCB, each Test and Operations Board, all users, and contractors. The objective of this group is to assure that the required software release with the appropriate changes are available to the users as negotiated and as approved by the OASCB. Consequently, to assure that the proper communication is being made, specific

individuals of each applicable organization are named as contact points and charged with the responsibility of its organization for the team.

In order to assure that the management responsibilities are clearly delineated and controlled, each organization has developed a specific plan detailing its responsibility and limitations. These documents are controlled by the OASCB. The emphasis is on the delegation of the management responsibility to that level that was involved in the actual development of the software, its requirements, and the interfaces associated with those requirements. Specific requirements, interfaces, development specifications, and other documentation utilized in the development activity are maintained current and are enforced by the OASCB.

The design of the mass memory program involves ten separate subprograms which are comprised of further subprograms. All aspects of the programming effort are controlled and documented, i.e., tape storage space allocation, type tracked tapes, and data location on tapes. Each corrective action or change to a program is controlled by documentation, by a quality control center, and by maximizing utilization of design personnel.

In recognition of the need for changes and updates to delivered software, specific categories of changes have been identified to facilitate planning of when a user can expect a change. There are four classes of changes depending on

the amount of compilation required by the release. Each major release has a documented release date (two month interval) and is specifically controlled as to content, scope, and need. In addition, plans have been developed to assure responsiveness and control considerations by providing update releases as required.

Documentation requirements are enforced by utilizing an Integration Plan whichprovides specific documentation requirements for each release. These requirements are delineated in the plan and each using activity is given an opportunity to specify the type and extent of documentation it requires for a specific release. The version release documentation accompanying a release is explicit in specifying the contents of a release, its utility, authorization, and impact on the master tape. All documentation utilized in the development activity is maintained current and is required delivery to the users with each major release of software. This documentation is available to the users to facilitate the utilization of the software.

The requirements for the Mass Memory programs were developed in conjunction with the users and those organizations specifically charged with that development responsibility. The involvement of the users is stressed in the development process, throughout the implementation process, and in any changes that may be required for that software after development.

The users are totally involved in all aspects of the management system. They participate as members of all control boards and in all working groups. Specific responsibilities are assigned to the users as to the application of the software, its function, and its utility in the users' environment.

Testing in this management system is mainly conducted concurrently with utilization. Except for testing performed by a Test and Operations Board to assure a program's integrity, operability, and performance, the main part of the testing is done after the software is put into use.

The Executive Steering Committee for this management system is the OASCB. Their management philosophy has assured that there exists minimal management layering, that priority problems are addressed and that effective communication between all involved organizations is assured.

The ability of the OASCB to provide the degree of responsiveness and control in this management system is due in large part to the fact that the majority of its activities and personnel are a contractor performed function. As such, this alleviates the OASCB of problems associated with personnel considerations. The ability to provide 24-hour response capability is directly due to this fact.

Tactical Air Force Command, Control and Intelligence Software and Management System

The philosophy used by the Tactical Air Force in its management system is to assure the compatibility and interoperability of current and future tactical Command, Control, and Intelligence systems. Extensive discussion of some of the management principles is not possible due to the security classification of the appropriate documentation.

In terms of responsiveness, the main consideration is the alleviation of the problem or implementation of a requirement but not at the expense of the Command, Control and Intelligence system that has been certified for use in multiple theaters of operation. As such, the concern is to provide the most expeditious resolution of a change, whether problem or requirement, and to verify that change extensively prior to utilization in order to restore operational readiness as rapidly as possible. The tradeoff in responsiveness and control is on a degraded system versus a system that is made inoperable due to implementation of a change without adequate testing and validation. Utilization of an uncertified change is limited to those areas where the Command, and Control, and Intelligence system has not been certified. In this context, turnaround of a problem or change is rapid but authorization for use in the Command, Control, and Intelligence system is limited. Consequently, testing of a change is much more extensive than normally performed.

Control is maintained through the Tactical Air Force Configuration Management Board (TAF CMB). All actions that affect a Command, Control, and Intelligence system require authorization by this board prior to implementation in a system that has been certified by this board. As such all aspects of the management system are specifically controlled by the board, i.e., interfaces, problem reporting, procedures, system description, standards, change procedures, and message standards.

In order to facilitate communication, specific standards have been established controlling all aspects of communication between organizations. Each organization involved in the resolution activity has specific requirements to provide, develop, or communicate information to those other activities involved. The organization responsible for resolution of a problem is provided direct interface with users. This direct interface is accomplished by the Computer Program Configuration Sub-Board (CPCSB). It is these boards responsibility to validate a problem, determine its operational, support, and utility impact, verify interface impact, and develop a corrective action. Communication in this instance is facilitated by the fact that the members of the boards are all users of the software and as such have a commonality of interest in the resolution of the problems.

The management functions of assuring the optimal allocation of the corrective action and the associated ramifications to the system affected is performed by the extensive

testing required on all changes prior to implementation and certification. Of the activities devoted to resolution of a problem, a major portion is devoted expressly to testing a change and assuring that it does not impact an established interface, is allocated appropriately, that corollary impacts are nonexistent, and that the system's integrity and operability is maintained. In order to accomplish this activity, an extensive delineation of responsibilities for the various organizations involved has been developed to assure all aspects of the testing operation are performed, verified, reviewed, and evaluated. Each of these organizations has specific responsibilities in assuring the validity of a change and its correctness.

The design problems normally associated in the military environment with the transfer of software from a contractor development organization to the military are avoided in this management system. This is because the software is developed in-house utilizing the software developed by contractors in conjunction with in-house development activites. Specific organizations are assigned the responsibility for developing requirements, interfaces, standards, and documentation for all aspects of the design effort.

Extensive planning does exist to assure that the required testing is accomplished.

Since the software is developed in-house, complete and thorough documentation of the software is possible. Documentation normally lost in the transfer activity does not

occur to this in-house development. The validity and content of the contractor provided documentation is not as essential to the maintenance activity since the software development is basically an in-house activity reflecting the operational requirements of the Tactical Air Forces.

In the instance of a Command, Control, and Intelligence system, the emphasis is on the interfaces that the system must have in order to provide an operational environment for the various weapons systems that will interface with it. As such these interfaces are strictly maintained and controlled. Extensive effort is expended in assuring the currency of these interfaces and their universality.

The Tactical Air Force is a user function and as such has the total involvement of all users. The Tactical Air Command is the lead for the operation of the management system but has direct involvement from all organizations that will interface with the Command, Control, and Intelligence system.

Testing is the most critical element of a Command, Control, and Intelligence system. Extensive testing is devoted to validating all changes prior to implementation. Upon successful completion of all aspects of testing, the system is certified for use by all interfacing activities.

The Executive Steering Committee is the TAF CMB. Its management philosophy is on assuring the interoperability and compatibility of its baselined systems. There exists no management layering between the users and the corrective action

personnel, priority problems are strictly controlled, delineated, and user oriented, and emphasis is placed on effective communication of thsoe changes required and those authorized for use. The total orientation of this group is towards assuring compatibility and interoperability of certified Command, Control, and Intelligence systems.

The activities of this management system are personnel dependent. However, in order to overcome this situation, unique identification of the required personnel is being performed (permitted by the career identification scheme in the military) to control human resources. Consequently, personnel requirements are not adversely impacting the management system.

Warner Robins Air Logistics Center F-15 Avionics Software Management System

The management philosophy for providing responsiveness and configuration control for the F-15 avionvics software is:

(1) the achievement of performance, schedule, operational efficiency, and readiness objectives for the software programs controlled,

(2) allow the degree of program maintenance, design, and development flexibility coupled with the appropriate degree of configuration control,

(3) assure efficiency in changes considering necesnity, cost, and timely implementation,

(4) and assure uniform application of configuration control requirements.

Although the operational concern exists within this management system for responsiveness to users, the capability to provide that responsiveness is not present in the system as presently constituted. This conclusion can be drawn from three major factors present in the system. First is the method of classifying the various discrepancies that enter the system. Second is the utilization of the G026 Material Improvement Project (MIP) system which monitors and controls all activities associated with the processing of discrepancies. Third is the utilization of "blocking" for all changes. In the first instance, the classification scheme, all discrepancies that are neither safety nor combat required are classified as a routine change. This classification is detrimental when introduced into the G026 system. In order to understand the magnitude of this classification and G026 impact on responsiveness, one needs to understand that all changes for mission requirements, no matter how important or extensive, are classified as routine if there is no safety or combat implications. For example, the target box through which a pilot views his target could be erroneous but since this discrepancy does not affect safety and is marginally combat, this discrepancy could be

classified as routine. The class of a discrepancy determines how long it will take to be processed and thereby affects responsiveness. Basically, according to the G026 system, a no kit corrective action that involves safety is allowed 15 days for resolution, one involving combat conditions is allowed 60 days, and a routine change is allowed 120 days. In addition to these foregoing conditions, the practice of blocking changes as discussed in the previous chapter compounds the response delay. The factors of classes, G026, and blocking have a direct adverse affect on the responsiveness. The user in this instance is not involved in the activities associated with resolution of the discrepancy other than the monitoring of the progress of the logistics personnel in resolution of the discrepancy. Once a class is assigned to a particular discrepancy, that assignment is permanent and is not normally changed. Through each station of the processing requirements for a discrepancy, time allowances are associated with each station which directly adds to the processing time and detracts from the responsiveness of the system.

The centralized point for control of all software changes is the Air Logistics Center's Configuration Control Board (CCB). This board exercises control over all changes for software under its control within a specified cost amount for a particular change. Changes exceeding the cost amount are forwarded to Headquarters Air Logistics Command for

disposition. Associated with the CCB is the Computer Program Configuration Sub-Board (CPCSB) that is responsible for verifying the need of a change, performing an impact evaluation, determining the required action, and providing a recommendation to the CCB. Before, between, and after these two boards are various other groups that must review, document, and process the change. Each of these groups has a G026 time allowance associated with its activity. This process is exclusive of any users. The actual control aspects for the software is focused in the Engineering Resources Branch located in the Engineering Division of a Center. This group is assigned the responsibility of verifying the validity of the change, providing a recommended corrective action, and after approval initiating corrective action. At the time of CCB approval, there has been no authorized effort expended in performing a change. This effort is initiated subsequent to the CCB approval. After corrective action has been completed, the CPCSB again reviews the action prior to release. The processing requirements of the management system are extensively documented with each in compliance with a higher management level requirements document.

There exists minimal communication between the users and the logistics personnel performing a particular corrective action. The users are not involved in the deliberations of the CCB or of the CPCSB. In fact, there is no mention of the users participating in any of the functions associated with the corrective action. There do exist extensive

processing steps and levels of management between the initial submittal of a discrepancy and the function that determines the recommended corrective action. The communication between these functions is performed primarily by mail. Work on a discrepancy does not initiate officially until a formal request for a support (letter) is submitted to the Engineering Division. Determination of the required action for a discrepancy or the intent of the users in submitting a discrepancy is exclusive of the users. In the event that a discrepancy involves or requires action by another Air Logistics Center, the entire process has to be repeated. For joint efforts with another Center, the activities at each of the centers are independent of the other and correspondence is primarily by mail.

The management functions of optimally located changes, effective maintenance, verification of corollary impacts, integrity, and operability are the responsibility of the Computer Resources Branch of the Engineering Division in a Center to the extent of its assigned responsibility. The total responsibility for a system may or may not be assigned to a single Center or division in a Center. Portions of a system that are the responsibility of other Centers or other divisions in a Center are not integrated in an overall total effort. Within the scope of its assigned responsibilities, the Computer Resources Branch is responsible for the total management of the software.

The design of the software received by the Center for management is the result of the development effort by a contractor responding to the requirements of a different procuring organization and philosophy. There does not exist any requirement for a specific language, structure, or modularization in the design effort. There is no specific requirement on the extent of documentation required for the logistics effort other than top level specification requirements. There are no requirements for traceability of the contractor's development efforts, corrective actions, or special actions taken in developing the software.

Planning for the management of the software can be summarized as (1) planning to assure the management system is in compliance with G026 requirements and (2) planning a management system which utilizes the blocking concept to the maximum extent. Of the two, blocking is the most disruptive, with time requirements for performing changes being expanded in order to perform all actions required for the entire block of changes. For example, Sacramento Air Logistics Center originally initiated a program of blocking to produce changes in a twelve month cycle, then went to a fifteen month cycle, and now is considering extending to a eighteen month cycle. (A cycle is the time required to get a change to the user subsequent to its identification for a particular change block.)

Documentation within the Air Logistics Center environment is totally dependent on that data acquired by the procuring organization. Historically, the communication link between the centers and the procuring organizations has been weak and as such insufficient documentation is acquired.

Requirements are generated totally on the information received in the initial communication of a discrepancy. The users are marginally involved in the requirements process if at all.

Users are not on any control board, are not involved in any corrective action, and have no responsibilities for a discrepancy once received by a Center. The users agreement or concurrency on a change is not solicited other than to formally concur in the manhours required in the field implementation of the change.

The testing requirements for changes released by a Center are extensive and have resulted in increased block change time requirements. However, when a change is released by a Center that change enters verification testing by the users prior to utilization. Whether this testing by users is a result of the lack of user involvement in the corrective process or distrust of the center's ability is unknown. However, its occurrence questions the need for extensive testing by the Center and the need for involvement of users in the change process.

The Executive Steering Committee for the AFLC management system is the Air Force Logistics Command Headquarters Logistics Operation Division. This is based on the fact that all actions, requirements, and procedures initiated by a Center are in response to specific requirements and directions levied by this division. Due to the presence of communication problems, priority problems, and extensive management layering in the AFLC management system it can be summarized that this division is either unable or unwilling to perform its function. It appears that its management philosophy as implemented is diametrically opposed to providing software that is responsive to users requirements and appropriately controlled.

Personnel is a critical factor in the Centers due to the inability to maintain qualified, capable, and experienced personnel. These problems are due in part to the management system and its unresponsiveness and extensive control requirements. Another major cause is the availability of highly lucrative and rewarding positions external to the government environment.

Software Management Principles
Conclusions

The Air Force Logistics Command's management system as typified in the Warner Robins Air Logistics Center management system is not capable of providing ECS support to Users in a responsive manner. The system is capable of providing

support but at the expense of timeliness and lengthening corrective action time. In order to provide support that is responsive to Users and ECS that has the appropriate degree of control required of its content, the following changes to the management system must be made.

The management system's orientation must be directed towards responsiveness to User requirements in the operational environment for the ECS. The Users must be specifically involved in the formulation of those requirements and in the modification of the ECS when it is not in compliance with those requirements. The Design requirements for the ECS must take priority over the existing code of the ECS. The guideline used for determining actions required must be dictated by negotiation between the software support organization and the Users. A management information system (G026) must not be a factor in determining the timeline requirements for corrective actions. In particular, the timeline requirements as specified in the G026 system must be deleted as applicable to ECS. These timeline requirements must be negotiated and established by the Screening Panel at its meetings.

Blocking of changes must be a function of the requirements of each individual change and not conversely. Blocking of changes is required by the support organization to provide economical and efficient support in its operations. However, the block in which a change will be accomplished

must be negotiated at the Screening Panel utilizing the required need for the change by the Users, other existing required corrective actions, and scheduling requirements. Blocking considerations must not dictate the time for corrective action accomplishment. If done, this will subsequently impact the corrective action time.

The G026 information management system must be responsive to the management system's planning decisions and not conversely. The functions associated with this information management system must operate in parallel with the basic functions of the management system or not exist at all. The timeline requirements of the G026 system must be deleted with the individual time actions required for a change decided by the Screening Panel.

There must exist direct real-time communication interfaces between Users, the Software Engineering function, the Computer Program Screening Panel, the Computer Program Configuration Sub-board, the Configuration Control Board, and the Software Release function. No function must be inserted between any of these functions in a support, communication, or any other type role. Minimal management layering is necessary to reduce the impact experienced by the management system from any other function being introduced into the management system.

Headquarters Air Force Logistics Command has the responsibilities for the Executive Steering Committee function. This Committee is fundamental to the success of the management system for ECS. In addition, its diliberations over the orientation of the management system must be developed in conjunciton with ECS Users.

The Software Engineering function at an Air Logistics Center must have direct interface with the Users of the ECS with problems and corrective action requests coming directly to this function. It is the responsibility of this function to determine the criticality of an ECS change. This determination must be done in conjunction with the Users to specify the requirements for each change. It is also this function's responsibility to determine if the required change is within the original design requirements for the ECS. If it is, the function must provide a determination of the action required to bring the ECS in compliance with the requirements. If it constitutes a new requirement, the function should determine the extent of the requirements, its impact, and the cost of performing the change.

The Computer Program Screening Panel must be comprised of the System Manager, the Software Engineering function, and all Users. The objectives of this group are to determine the priority of each change. This group must identify and specify a plan detailing the corrective action for each change. It also must negotiate the extent of testing that

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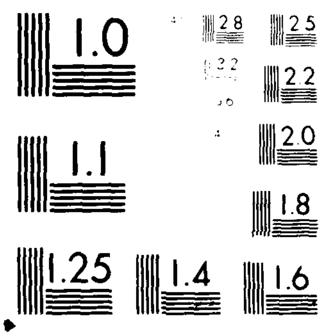

MICROCOPY RESOLUTION TEST CHART

must be accomplished by making tradeoffs between that to be accomplished by AFLC and that to be accomplished by Users. Each individual on the Screening Panel must have clearly identified and delegated responsibilities for establishing the position of his parent organization. The purpose of these Panels is to perform all of the logistics functions required for each change in coordination with the Users, corrective action personnel, the testing organization, and the ECS manager.

The Computer Program Configuration Sub-board's primary function is to provide approval for either an in-house corrective action, processing of the change to Headquarters AFLC for approval, or initiating procurement action. Based on its decision, the responsible parties must initiate the appropriate action.

The Engineering Function is to assure the operability, maintainability, integrity, and supportability of the ECS. It also assures that the requirements for each change are specifically satisfied by the appropriate corrective action. It is to work in concert with the User to assure that the requirements for a change are understood and that the appropriate action was taken. It also is to assure that the proper documentation is prepared prior to release of the software. All of its actions are dictated by the plan negotiated by the Screening Panel and approved by the Computer Program Configuration Sub-board.

The Center's Configuration Control Board formally approves all software releases to the Users. It is the checkpoint that verifies that all of the milestones and agreements of the plan negotiated by the Screening Panel and approved by the Configuration Sub-board have been complied with as negotiated.

The Release function is that organization that assures that the software being released complies with all requirements of the plan negotiated for the corrective action, that the release contains only those corrective actions specifically approved by the Configuration Control Board, and that all documentation and tape requirements for the release are on hand prior to the release.

In general, the management system for ECS within the Air Force Logistics Command can be benefitted by applying the software management principles. The flexibility and real-time capability of software necessitates a management system oriented to its environment. The adaptation of a management system developed primarily for hardware items will not have the flexibility, change capability, and management emphasis that software management system requires.

Chapter V

SUMMARY AND CONCLUSIONS

The management of Embedded Computer Software is a critical activity in the future of the Air Force Logistics Command. As more weapon systems have Embedded Computer Systems, the ability to provide responsive support and effective support by providing controlled software will dictate who will have that management responsibility. The management capability to provide support that is responsive and does not adversely affect control is possible. The inability of AFLC to currently provide responsive support highlights the need within this organization to change its management system to provide responsiveness. If it does not, the consequences can be grave. The management system responsibility for this software will be assigned to those organizations which can provide this necessary responsiveness support but who may not be able to provide adequate control. Relying exclusively on hardware is not sufficient to assure the continued existence of AFLC. Quality support and responsiveness must be forthcoming for Embedded Computer Software systems.

The basic problems in the current AFLC management system are attributable to its utilization of proven hardware systems and its reluctance to provide a more dynamic management system for ECS. The problems apparent in extending corrective action times, unresponsiveness statements by Users, and internal management problems are due to utilization of antiquated management information systems, hardware-oriented procedures, and limited responsibility delegation. The restructureing of the management system for ECS in AFLC around the four basic functions is possible, however, extensive documentation changs in terms of requirements, regulations, and operating instructions must be accomplished prior to any formal change in the management system.

The excuse used perennially in AFLC of inadequate documentation, although valid, highlights the reluctance of this organization to take corrective action. Extensive documentation and research has been performed on what software documentation is required for maintenance activity. However, AFLC has not taken action to initiate these corrective actions in their operations even in upgrading its contractor Version Description Document requirements and in Program Management Responsibility Transfer planning.

The orientation of a management system to user requirements and assuring the software is in compliance with those requirements is not an objective in AFLC currently. In order to alter the management system to pursue these goals, a total reorientation of the management system for ECS is required.

The current capabilities in the AFLC management system for ECS are being experienced due to the transfer of highly qualified personnel from external organizations (NASA and civilian contractors). As economic conditions improve, or, more likely, as the AFLC management situation finally reaches the point where these individuals no longer can cope with the system, these valuable resources will leave.

Currently, AFLC is pursuing a hodgepodge approach to testing. Individual weapon system ECS applications are being provided multi-million dollar facilities to perform testing of ECS that is being acquired with inadequate control with minimal documentation and that will be controlled by a management system that is totally inadquate.

The recommendation of this paper is the implementation of the basic four functions within the ECS management system and providing to these functions the management tools to effectively perform their responsibilities. Figure 3 is a summary illustration of this Recommended Management System. This figure identifies the various functions of the management system and lists their activities (*), outputs, participants, and primary concerns in software management principles (**).

Additional research in the activities of each of these functions is needed. Such research would be beneficial in terms of what actions are required, what type of personnel are required, and the standards associated with their actions.

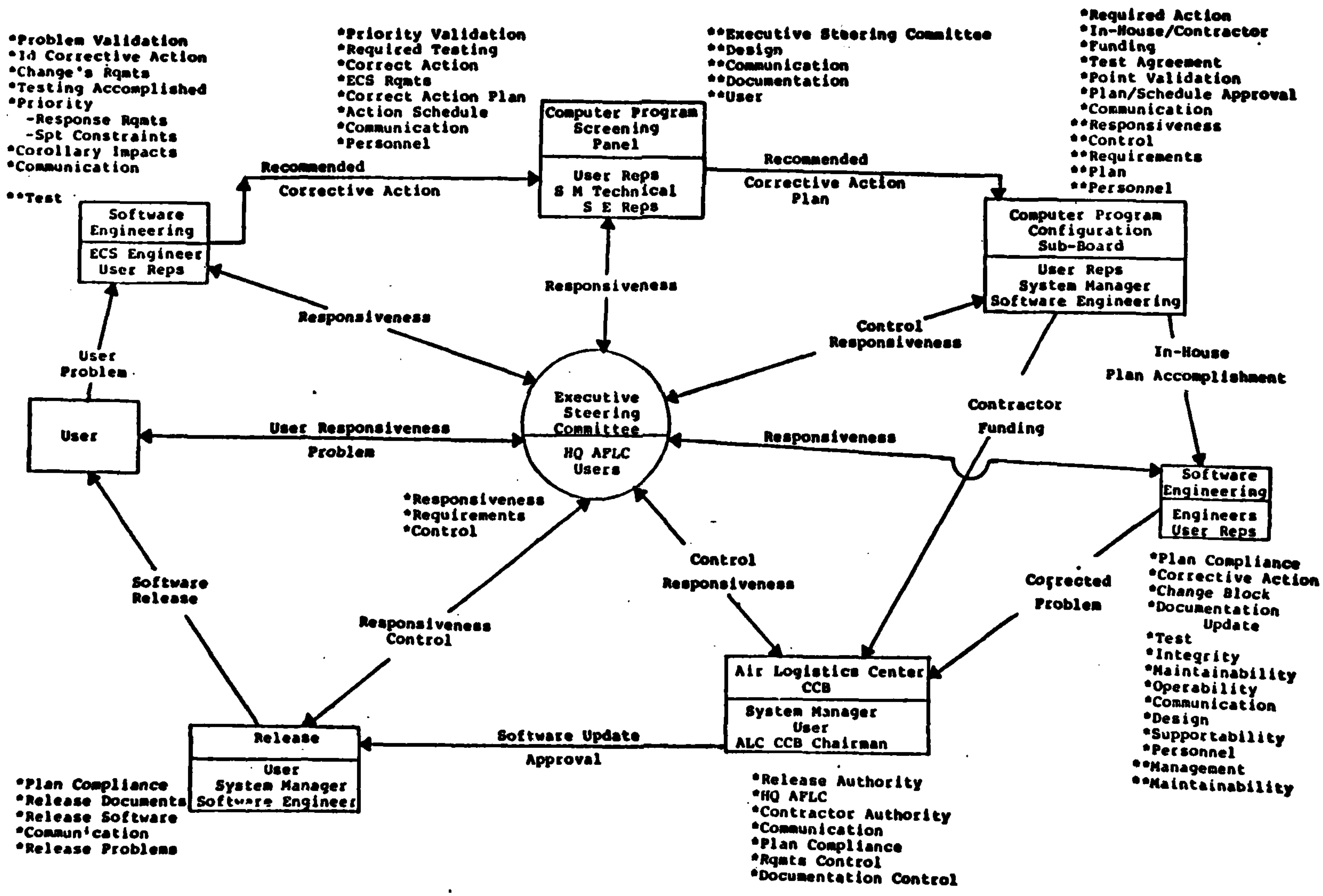

Figure 3
RECOMMENDED MANAGEMENT SYSTEM

Of particular importance, is the development of standards for evaluating the performance of responsible individuals and functions of the management system. The ability to identify specific deficiencies within the management system based on comparisons of performance to the standards would greatly contribute to the ability to modify the system in order to provide better support.

In conclusion, the basic principle of user participation would contribute greatly to the ability of AFLC to provide support that is responsive and ECS that is controlled.

APPENDICES

APPENDIX A

RESEARCH RESPONSIVENESS AND CONFIGURATION CONTROL REQUIREMENTS

RESPONSIVENESS

Responsiveness encompasses the operational concern of maintaining the ability to make rapid changes to ECS which is impaired and that is critical to the operational environment (1:12). The desired result of an operational change is that the change is accomplished in time to meet the responsiveness requirements of the user and is effective and supportable within economic considerations (1:10). The management structure associated with ECS is the determining factor in the ability to provide the responsiveness required and desired. Responsiveness is the primary consideration of the organization providing support. Responsiveness, however, includes the principles of system management, system engineering, system test, and configuration management (1:10). For the user of ECS, responsiveness considerations are the dominant criteria in any and all support decisions. The user evaluates responsiveness in terms of the "quickness" of a response to their requests for support (31:139). The primary user concern is that their demands for operational changes take priority over other work in process or awaiting action, such that the change has immediate attention and resolution (12:156). This necessitates the identification of the criticality of the request, its associated corrective action, and its

subsequent release version making the enhancement available. Perennially, one of the areas of friction between users and System Managers lies in this area. This friction is that users do not get the attention they want as quickly as they would like. Inadequate response by the System Management function to user needs invites the formation of user teams in the operational environment to correct the problems that it is confronted with. Therefore, the prompt handling of change requests from users creates an atmosphere of credibility for the System Manager and decreases the likelihood of the formation of these user groups. The determination of the criticality of a change is complicated by the fact that troubleshooting and problem isolation in a real-time ECS environment can be extremely complex. When a real-time terminal-oriented ECS fails, the user is immediately aware of the problem and pressure immediately builds to resume and restore the operational capability. Extensive research by the Rome Air Development Center has shown that repair time for a software system increases exponentially and is dependent on the program's complexity.

As previously stated, required responsiveness is determined by the criticality of the change request and must be done by an evaluation of actual priorities existing within the support and user organizations. The establishing of priorities for ECS change requests is determined by what is important for the operation of the weapon system. The judgement of the criticality and the associated priority

are based on the actual change request and ECS documentation (29:71). The steps involved in this evaluation are the change request definition, priorities assessment, and the objective of the change request as determined by the user, his needs, and other existing change requests in total (17:3-110). This evaluation must be performed as early as possible in order to specifically identify the operational impact to the user (18:63). There must be an established method of indicating the seriousness of a change request with the highest priority assigned to those requests with the most serious requirements. Subsequent to change request definition and priority assessment, the change request requires scrutiny for justification of validity, exhaustive ECS tests to determine associated problems, testing of the release version, and testing of the ECS with the release version incorporated. Only versions that are evaluated to be effective, reliable, and cost efficient should be released (5:34).

The easiest way of providing the user required responsiveness is to allow the user to accomplish all change actions. If changes in this instance are made without effective change control and documentation, at the very least, the introduction of later changes will be more difficult and the complexity of the program increased. When users of ECS are allowed to take corrective action, the result is often too rapid action in a complex technical environment. These erroneous changes by users may change

or alter the original ECS design requirements, intentionally or unintentionally. Subsequently, these errors would have critical implications for planned modifications or result in induced errors to the ECS. Therefore, users are discouraged from making corrections to ECS. Often users approach the situation where a problem has occured in a crash project atmosphere which results in corrective action that is adverse to the software, the documentation, and the overall management of ECS.

In an environment where responsiveness is important, documentation is essential to determining the changes required. When a change request occurs, the needs of the change request and the associated compromises are documented and understood by both user and System Manager. Care is taken not to duplicate any previous work but to capture and utilize to the maximum extent lessons learned from other ECS applications. If a change is required, the change is thoroughly documented in all documents and manuals. The code is updated to concur with the new baseline.

Problems that are designed into ECS are the result of: (1) fuzzy or poorly defined or contradictory requirements, (2) vague and overlapping specification, (3) unreadable and hard to maintain specifications, or (4) the level of coding. Most software change requests resulted from problems in design structure and system description (incorrect, incomplete, or unreadable requirements) (28:122). The amount of time to be spent by the programmer searching for the

problem and possible solutions is a function of the complexity of the program and the importance of the problem. The type of error (Appendix B) is subjective and can differ from programmers in type, class, and priority. Even in the event corrective action is taken, absolute proof cannot be provided that the error was corrected and removed with certainty. Viewing the corrective action efforts of a programmer, the speed at which he can isolate errors, determine the required level of corrective action, and take that action is a function of ECS structure, its complexity. Of the various math models advanced for predicting error occurrence, resolution, and mean time between failure, none have been satisfactorily proven to be an effective predictive model. Failures of software in terms of the time required for corrective action are in general exponential in occurrence, debugging, and recurrence (33:22). Existing tools utilized for hardware failure rates cannot be applied reliably to software to derive a failure rate (28:122) for basing required responsiveness of a support organization. These inabilities impact the ECS support organization's capability of providing effective responsiveness to the user. The estimating tools of Bayesian probability addressing errors existing in a program, errors corrected, and errors attempted to be corrected provide the best time requirements for application by a support organization for determining responsiveness capability to an operational program (11:2).

CONTROL

A well developed philosophy of ECS control establishes a basis for effective responsiveness and configuration management for the user and support organization. The control requirements are utilized in measuring performance of the support organization in providing responsiveness and configuration control (31:9). There exists so ideal model for prescribing the control features required by a large-scale software support operation. The extent of configuration control is dictated by the controls required to insure that the software's integrity and supportability is maintained (1:18.6). A single point of management is established with comprehensive control over the ECS with the authority to allocate changes effectively between hardware and software (1:10). This single point of management must have all decisions concurred in by the users. It should directly involve the users in the decisionmaking process. The main function of the single point of management is the defining and controlling of the ECS baseline, controlling all changes thereto, and assuring that hardware and software match and are in accordance with the approved baseline (1:10). This single point of management for ECS should minimize the management by reaction process typical of large software operations (32:3.187).

The utilization of multilead or multi-responsibility control concepts for ECS either in the development or maintenance of software results in failure to produce a viable software product. Firm control of the ECS is necessary to provide for change request action, realistic time response estimates, minimize costs, and effective program utilization (10:137). An effective network of involved organizations's external and internal control responsibilities is an important factor in the success of an ECS and should exist and be applied throughout the life cycle of the ECS (8:61). The type of control in terms of accuracy and discipline requirements is jointly determined by the System Manager and the users of the ECS (9:111). It is necessary to adopt stringent management control techniques to ensure that the ECS actions required are performed and the desired functions obtained as accurately as possible. This requires control over the introduction of updates to the ECS by insuring that the necessary control steps in data gathering, collecting, recording, transmitting, processing, storage, retrieval, dissemination, and usage have been utilized (14:2.1). Associated with the origination of a revision to ECS, the proper controls must exist to ensure the accurate and timely development and distribution of updating source documentation to existing documentation (30:2.15). Changes to either the ECS or the documentation must be controlled to insure correctness and prevent error. The key processing functions of the control function must be

assigned to different individuals to insure that unauthorized or erroneous transactions cannot be entered into the ECS without being detected and prevented (34:1.109). These individuals insure that specific tasks are accomplished efficiently and effectively and monitor progress towards resolution of a change request within the applicable response requirements. In order to assure effective control between these individuals, the interfaces between them must be well defined and managed with minimal time impact to responsiveness and the overall control being derived for the ECS from the organizations relationships within which these individuals operate (12:45).

The rules and procedures that dictate the type of control to be exercised is fundamental to the effective initiation of change request action. The essence of ECS control lies in the ability to apply measurement standards to the quality of support being provided within the time, cost, and performance constraints dictated by responsiveness and configuration control (36:4). However, standards of control and disciplines required do not usually exist, and this impacts the ability to maintain ECS effectively (35:3.69). A major problem, therefore, is the defining of standards that can be utilized to measure effective support (26:3.1).

In ECS control, the objective is to centralize maintenance activities as much as possible in order to maximize efficiency while making sure users' requirements and operations are not impaired and to establish checks and balances

between users' responsiveness requirements and control requirements of the support organization. Within the bureaucratic organizations present in AFLC, the demand for control by the System Manager frequently takes the form of increasingly extensive coordination requirements to ensure reliable behavior (15:125). This form of control impacts the capability of providing the responsiveness required by the user. The location of an ECS System Management organization is dependent on ECS objectives, the organization's size, the available talent (personnel), and the required geographical deployment requirements of the ECS (12:44). Decentralization of the ECS management responsibility, as currently done in the Air Force, insures that users have their applications defined and programmed by personnel who are familiar with user internal operations and operating requirements. The disadvantage of this mode of operation is that the user does not consider all of the software and hardware ramifications of a change request in its resolution efforts. Centralization of the ECS management function within one command has benefits in terms of: more economy, greater control, more efficient utilization of talent, greater coordination capability, elimination of duplicative efforts, better integration of hardware and software, and greater testing capability. Disadvantages associated with centralized management are user communication problems, priorities problems, and lack of top management involvement (3:115). However, the most effective

management method is centralization where organizations performing similar functions can cooperate on change requests without impacting quality of responsiveness to the user (12:44). A primary consideration in a centralization effort is the users' role and their relationship to that organization providing support. Another fundamental consideration is that when input preparation work for ECS changes has been assumed by a central staff that any unfamiliarity of that staff with the ECS requirements and needs should be communicated to the users and resolved with the users prior to implementation.

COMMUNICATION

Communication between the user and the ECS System Manager is critical (29:14). ECS requirements should be defined and developed in close coordination with the user. This development is dependent on the existence of good communication between the two. Frictions that are present between the users and the System Manager result from communication breakdowns. A byproduct of this breakdown is ECS that is ineffective and behind schedule (8:51). In order to maintain the required communication, the System Manager must have the total support operation sensitive toward and coordinate extensively with the user. The initial information provided to a maintenance programmer by a user or a System Manager is of great importance since

erroneous information tends to be compounded and will lead to remedial efforts that are far from the actual change request (25:50). The communication channel between the user and the System Manager must be sifnificant and an important feature between the two organizations (1:18.6). The lines of communication must be short and have great continuity and awareness built-in as to reporting and responding. The emphasis must be on a direct interface level between the System Manager and the user with communication and understanding of requirements essential. Attention must be focused by both the System Manager and the user to maintaining the rapport and coordination relationship of the communication channel (29:146). The System Manager must have the capability of interviewing the user to document viewpoints, needs, and concerns associated with ECS. This necessitates open communications, laterally as well as vertically, within the System Management function and between it and the ECS users. Any cutoff or breakdown of communication seriously undermines the effectiveness of the System Manager in regards to configuration control and responsiveness. A supportive relationship must exist and assure the maximum effective communication is allowed and that the environment is conducive to information flow (19:47). This means minimal management layering between user and the System Management and the minimization of extensive in-house coordination requirements. Communication

with the user is a vital factor in the effectiveness of the System Management function and is the make-or-break factor in responsiveness and configuration control (8:52). The requirements for communication extends throughout the life cycle of a change request, initiating with required change identification, through request resolution progress reporting to the user and date of resolution availability, to resolution release.

MANAGEMENT

The key functions of the management function is to assure (1) that software changes are optimally allocated to the appropriate system, (2) that effective maintenance of the total weapon system is performed, (3) that potential corollary impacts from changes to hardware and software are identified and considered before implementation, and (4) that the weapon system's integrity and operability is maintained (1:10). This places a great inherent need on the organizations involved with the ECS to have their responsibilities delineated and defined. The degree of responsibility delineation and definition determines the effectiveness of the ECS support effort and the ability of the organizations to mobilize their resources to respond to a change request. The management effort must be directed towards total technical directing, controlling, and integrating of all support efforts associated with the weapon system. ECS must be managed as an integrated entity to

insure the maximum flexibility and to insure responsiveness to user requirements. The System Management organization must exist to achieve the level of control and responsiveness required by users. The support organization's effectiveness is determined on the basis of their achieving the level of control and responsiveness required (15:4). The support organization's structure is an influencing factor on the ability of the organization to perform effectively. When the support organization has no single focal point for the support, fragmented, ineffective, and inefficient support will result. One of the most important internal controls within the support organization is the delegation of responsibilities. Normally, this delegation tends to be informal and vague (8:28). Diffused authority or inefficent delegation in such a complex organization as is required for ECS support results in time lags and delays impacting responsiveness (21:27). In order to function effectively, the management structure of the organization must have compatible functions within the organization and external to it (19:123). The skill in managing an ECS support function is the art of matching the required technology with the precise needs of the user. This requires a clear delineation of the responsibilities that belong to the users and to the support organization (8:53). This responsibility must be clear cut in both instances and is critical to the successful support operation. The responsibility delineation must describe in detail the lines of authority,

limitations, and associated ramifications (9:42). In the formulation of responsibilities, the users are directly involved in policy setting, and the acceptance by the users of any formulated policy is mandatory. It is only with the users involvement that the System Manager can determine what the user needs, what weapon system impacts are present, how critical the change request is, how the change is to be employed, and how well the current ECS performs (36:57). The management function must be committed at all times to the actual status of the ECS and to assuring the most responsive support is being provided within the required configuration control requirements (36:40).

DESIGN

ECS design is the logic by which the weapon system receives inputs from the external environment, interprets the input, and then makes decisions that result in displays, responses, or commands to weapon system subsystems (2:31). The design requirements are derived by the user and any alterations or changes to those requirements requires the concurrences of the user (29:183). The structure of ECS is the method of developing the software program. Usually for software support considerations, the underlying concept is a top-down design which leads eventually to modular structure of the program (13:11). The top down design is a software programming method which starts at a very general level by identifying major functions and proceeds stepwise

to lower levels to the identification of lesser functions that are derived from the major ones (13:10). The design's unity in terms of structure and requirements is fundamental to both the user and the support function. The important ECS design concept is that each step is laid out and defined and will facilitate support that is responsive and within configuration control requirements (25:43). Changes that occur in an operational ECS are mainly due to design errors and not requirement changes. Design errors result from ECS that was poorly designed, inflexible, and required extensive higher generation computer technology. Design errors are more prevalent when the support of the ECS has been distributed among various organizations.

PLANNING

The lack of planning is a dominant cause of programming reworks and System Management failures to comply with responsiveness requirements (12:52). Planning for software maintenance in general is a function that is rarely accomplished (8:126). Planning includes development of a methodical procedure designed to provide an acceptable course of action for resolution of an ECS change request. Traditionally, planning is poor, with little or no time spent on this vital activity (16:3-192). The lack of strategic planning results in ineffective management and control over the ECS and impacts configuration control (26:3.7). In order to reduce the impact of implementation and conversion problems

associated with ECS, planning must be accomplished throughout the Life-Cycle of the program. Plans establish a course of action and provide management, configuration, control, responsiveness and related goals with which to evaluate performance (36:39). The organization and establishment of plans to deal with corrective actions is essential for change request resolution (27:4.5). The degree of planning performed determines the extent of control possible and the greater the extent of careful planning in all areas the more support flexibility the ECS has (22:73).

DOCUMENTATION

The extent and level of documentation required for each ECS acquisition is hard to evaluate since short comings in the procured documentation is not apparent until there exists a need (28:135). However, the lack of documentation is another make-or-break point for ECS responsiveness and configuration control. ECS is designer dependent and serious failures in the description of a system can occur when the designer does not or improperly documents his support actions (28:136). Traditionally, determination of the adequacy of the operational documentation for ECS is on the employee rather than on regulations or supervisors. The adequacy of the documentation varies with each programmer (35:188). Good programmers who optimize design coding are usually less skilled at documenting their actions. Instead, they

tell what that code does instead of what it is which is required (25:53). The existence of proper documentation minimizes errors that occur when trying to detect an existing problem (25:91).

For support of ECS after software acceptance, the quality of the documentation must meet standards that many organizations have not developed or are not meeting (31:77). An extensive listing of deficiencies are specified in "Report of Functional Management Inspection: Management of Embedded Computer Software" (2). Comprehensive and current ECS documentation is necessary for the continued efficient operation and success of any software maintenance function. The greater the correlation of the documentation, testing, and actual software code the easier the system is to support within response and configuration control requirements (28:126). The long term effectiveness of a complex ECS is dependent on the accuracy and adequacy of the documentation associated with that ECS. As the maintenance programmer moves between the documentation and the code in his maintenance activities the correspondence between the code and the documentation is directly related to the success and ease of his maintenance effort (25:51). Precise documentation of the characteristics of the code is essential and should be of an Air Force approved standard notation. This because it is easier to specify an ECS modification when that modification is referenced to existing clear and well integrated ECS documentation. All

changes, whether modification or problem resolution, must be documented by written statements showing reason for the change, its effect, and its approval. Each release of software must be accompanied by release documentation (12:284). All release documentation must be compatible with existing ECS documentation (29:267). The important consideration is that ECS documentation exists and is maintained current.

REQUIREMENTS

One of the most important contributors to the establishment of an effective response-oriented System Management function lies in the area of software requirements definition and documentation (8:180). The ECS requirements generation and definition phase is a user oriented activity and is accomplished in close coordination with designer and user (29:32). It is the responsibility of the users to specify in detail the requirements for the ECS, identify the application, and the environment in which the program will be utilized (9:116). When the users assume a major responsibility for requirement definition, there exist problems in the convertability of those requirements from the operational environment to the design environment. Therefore, it is implicit in the generation and definition of requirements that the requirements be in final form, relatively stable, and not subject to change. This necessitates that requirements be complete, consistent, testable,

traceable, and flexible (23:40). Users and the System Manager assess and assign priorities to the ECS requirements. This insures that the requirements do not preclude effective logistics support and that the required support is conducive to the user dictated responsiveness requirements for the System Manager (1:10). ECS that becomes operational that does not satisfy user requirements is usually the result of inadequately defined requirements or insufficient testing. Functions to be assumed by the ECS must be clearly defined and documented (10:73). The documentation of the requirements is in the form of functional descriptions, system description manuals, system requirements manuals, technical requirements manuals, and various levels of System and Subsystem Specifications. Deficiencies in user requirements documentation results in the wrong interpretation of user needs or design of ECS that is inadequate or not operationly suitable to its environment (26:3.8). Suspected errors in requirements necessitates clarafication both of the requirements in question and its documentation (18:72). The guiding principle in this instance is that requirements are generated by the user to satisfy an operational need and as such, the interpretation of those requirements must coincide with his needs (8:53).

The user operational needs translated into ECS requirements and the corresponding responsiveness required for support of those needs and requirements directs the establishment of support standards. A successful standards

program must have the direction and support of both the user and the System Manager management. These standards serve as support and responsiveness goals for the System Manager in his support function and as a basis for evaluating their performance in providing support responsiveness (20:81). These standards must address all aspects of the ECS and adherence to the standards must be diligent and serve as a working guide for the support function (8:133).

MAINTAINABILITY

The capability of the System Manager to provide the required responsiveness is directly determined by the maintainability of the ECS. The effectiveness of the System Manager in providing support and responsiveness is determined in large part by the ease of maintenance built into the ECS (32:3.189). The primary objectives in designing ECS and its changes are to minimize the amount of initial maintenance actions required to correct designed-in errors and to allow the necessary maintenance actions to be accomplished as rapidly as possible and as simply as possible (31:77). This equates to the reliability of the ECS. Software reliability is the probability that a computer program will perform to its intended function for a specified time interval under stated conditions (13:16). Dimished software reliability is due to bugs and errors in the program which result from poor design, inadequate testing, improper maintenance, and improper software

modification (10:136). The optimal maintenance path to be utilized for ECS is commonly not possible because (1) choice points and logical elements of a program are not well defined and (2) documentation is not adequate enough to allow the programmer to assess the "correctness" of his effort in providing corrective action (25:54). The changing of a program is sometimes more difficult than the writing of an original program because of the "rippling" effect of errors caused by the original error In addition, there are errors that are induced by the corrective action (5:45). Program changes or modifications can insert jumps into the program that further complicate the program and decrease its understandability and readability (10:141). Continual changes and updates to ECS increasingly make the program hard to understand and to maintain. When this condition is coupled with management's inaccurate, incomplete, and uninformed approach to software management, software maintainability is extremely impacted. The actions necessary to insure an ECS is maintainable requires creation of specific maintenance dedicated group to ensure incorporation of known ECS characteristics in the maintenance practices and identification of maintenance tools.

USER

The user is that organization that has the operational needs for which the ECS requirements were developed to satisfy. Consequently, only the user has the full knowledge

of the operational environment in which the ECS is to be utilized (29:13). When any ECS is accepted and placed in use, its operational use is determined solely by its users (32:3-190). Software that is maintained (1) with only average input from or understanding and support of users or (2) by those whom the user disagrees with, has an ECS usage failure probability rate that rises geometrically with lessening user support and participation (29:13). User ECS support is determined in terms of the reliability, timeliness, economy, range of choice, and flexibility of support the user receives from the support organization (31:9). Therefore, user participation must be included in every phase of the software's development and operation. The importance of users' concurrence and participation in support or operational decisions cannot be over stressed.

A symptom of inadequate software management is the lack of user involvement and commitment which is caused by inadequate user responsibility definition (16:3-193). The user's responsibility in the support activity is a critical factor in the ECS maintenance and support and those responsibilities require detailing. The user must take on a major responsibility for ECS support. There must exist a clear and detailed understanding of those responsibilities that belong inherently to the user's and those that are the System Manager's.

No ECS support effort can be initiated and accomplished successfully without user involvement and commitment to the software requirements (8:55). Software requirements determination are a user oriented activity (29:32). It is the responsibility of the user to specify in detail all the software requirements and the associated maintainability and responsiveness requirements. Once these requirements have been identified, it is important that the user commit to them and that they be defined rigidly and established solidly in the appropriate documentation (29:183). Since a substantial portion of the modifications or enhancements to ECS are user initiated, the user must be directly involved in the preparation of the policies necessary for successful support (10:73). There should exist a direct relationship between the user's plans and the System Manager's plans so that the latter provides the necessary support to assure the former can accomplish their objectives. In either case, key and final decisions in planning and probably in budgeting must be user supported (31:36). When responsibility for software configuration is vested in a support function, the System Manager familiarity with user needs and requirements and must minimize quality control and maintenance change requests (10:12). For maintenance change requests, there are basically two types: design and discrepance. Design problems occur when the software does not or does not seem to satisfy user operational requirements. Misleading user requirements or the accepting of

verbal user requirements as design objectives versus the documented requirements are the cause of user design problems (26:3-8). A functional description of the software provides the user with a clear statement of the operational capabilities of the system to be developed and requires formal user approval. Discrepancy problems are problems that are identified as a result of the operational use of the software. The user must define these problems explicitly prior to change development. The emphasis must be to assure that the corrective action corresponds to the problem identified by the user. The user must utilize effective management by attempting to the greatest extent possible to minimize continual changes which disrupt and delay the system's utilization (10:4).

TEST

The testing of ECS is one of the most important and most frequently abridged or skipped steps vital to an effective software program (23:3.193). The objective of the ECS test is to bring together all subprograms of the ECS and to verify that they fit together and operate smoothly as designed. There exists no theoretical way to prove that the software so tested is absolutely correct. This fact usually results in the failure to test or incomplete testing (7:18). However incomplete, testing of software changes to the ECS prior to release for operational use is vital to assuring that the system continues to meet the requirements specified.

EXECUTIVE STEERING COMMITTEE

The Executive Steering Committee is an organization established at the corporate level whose purpose is to provide overall software management guidance. The membership of this group is not specified except that a software user representative is mandatory (29:16). The Executive Steering Committee provides:

1. Approval and prioritization of software projects from a corporate view considering challenge, opportunity, and associated problems (5:31).

2. A maintenance philosophy taking into consideration controversial but necessary software changes and user approval and coordination (31:9-10).

3. Assessment and identification of critical software requirements (31:37).

4. Management decisions during development of complex programs (10:76).

It is this group that determines the orientation and success of ECS management by specifing management concept, a support posture, and the responsiveness requirements (4:156). In determining responsiveness and support goals for ECS management, the goal definition process is performed considering the software, its performance requirements, and the user required responsiveness and defining specific goals that are a realistic interpretation of these requirements. The effective utilization of personnel and resources and the

evaluation of the support organizations progress towards these goals achievement is a primary function of the Executive Steering Committee. Its operational role encompasses assessment of software support direction, instituting means to provide better support, and planning and participating and promoting effective communication between user ans System Manager (24:30160). The effective functioning of this group significantly assists efforts to manage software effectively and provides protection to lower level designers from sudden external pressures for software change. A critical function of the Executive Steering Committee is the careful nuturing of user communication and relationships and assuring that these activities extend from the corporate level to the day-to-day software support operations. The committee is the primary management organization responsible for assuring responsive support is provided users.

Most problems that exist between users and System Managers originate with this group. Problems in communication, responsiveness, and inadequate support are attributable to the Executive Steering Committee being comprised of individuals that are unable or unwilling to spend time to insure a firm grasp of factors significant to the economies of managing software effectively (36:25). Typically, this is when the individuals on the committee view the essential invisibility of software as an unsurmountable problem. The basic management rule that no manager with responsibility

will base critical and important decisions on a solution to a process which he himself does not adequately understand applies to the Executive Steering Committee. The visible evidence of an Executive Steering Committee that it is unwilling or unable to perform its function is user communication problems, priority problems, and management layering meaning that support and responsiveness to user requirements are adversely affected (3:115).

PERSONNEL

The greatest determining factor of where to locate the ECS support function is maintenance personnel availability. The maintenance programmer has absolute control over ECS and its operability. Consequently, the continuity of programmers is of paramount interest to the support organization in its ability to provide responsive and effective support. The emphasis in an ECS support environment is on teamwork and group supervision towards commonly accepted goals in terms of responsiveness and configuration control (21:30). The achievement of high performance goals by support personnel in terms of responsiveness and configuration control is directly linked to the personnel associated with providing that support. Many problems experienced in the ECS environment are the result of personnel problems and the degree of interdependency between ECS and the personnel maintaining that software. Personnel problems encompass the availability of qualified individuals, their continuity,

morale, tenure, capability, and experience (1:15). Continuity problems impact responsiveness and configuration control because as maintenance programmers depart the organization, maintenance slides, the maintenance capability decreases, error correction capability diminishes, and the capability to provide thorough analysis of problems is diminished (12:171). Software support is not a glamorous function and does not naturally attract qualified personnel although such are required (31:76). Program maintenance is often considered degrading work and programmers like to work on new projects, therefore the maintenance task suffers (5:45). The ability of a support organization to be responsive and support effectively is determined by the degree of turnover in systems analysts and programmers. Embodied within these individuals is much of the planning, specialized knowledge of the problem area, and detailed or unique solutions to the problems that are not documented or generally known except by these individuals (31:22).

Programmers that are assigned to the maintenance function are adept at finding and correcting difficulties often on the basis of meager evidence (5:109). Experience of these individuals is directly linked to their ability to interpret a program and diagnose theproblems (25:87). Comparison of novices and experienced programmers in the maintenance function indicates that the more experienced personnel can correct errors at a faster rate than the novices (25:142). This is a critical factor in an ECS

support function that is response oriented. The support organization must provide the greatest stability, rewards, and opportunity to experienced individuals that can perform the maintenance function in order that these individuals may be retained. In addition to experience, these individuals must be experts on the hardware capabilities, the software capabilities, and the required operational role of the system (8:183). These individuals must be the most sophisticated senior technicians in the software maintenance installation and form the hub of talent required to provide the necessary responsive support to the user (8:181). These persons are by responsibility of their job in a highly creative role and are expected to exercise innovative procedures in performing corrective action while performing in real-time (15:135). Because of skills and experience required by a maintenance programmer, the demand for these individuals is high and provides ample opportunity for them to leave the organization. A fundamental purpose of the support organization is to insure the continuity of support individuals and the availability of their indispensable skills.

APPENDIX B

DEFINITION OF TYPE ERRORS

Problem Specification Error - A mistake or deficiency which occurs in the analysis of the program application or in specifying the software requirements with respect to the intended program application such as incomplete, erroneous or ambiguous statements (13:17-21).

System Design Errors - A mistake or error made in the transformation of user-oriented program specifications into system design specifications (13:17-21).

Program Design Error - A mistake or error make in transforming system design into specific algorithms and data structures (13:17-21).

Coding Error - A mistake or error made in the transformation of program design into source language (13:17-21).

Clerical Error - Any human failure in the transformation of one step of a program's development to the next step (13:17-21).

Debugging Error - The inappropriate use of debugging tools, insufficient or inappropriate test case selection, or misinterpretation or debugging results (13:17-21).

Testing Error - The inappropriate or insufficient test, misunderstanding of functional requirements of a software program, or test plan deviation (13:17-21).

Implementation Error - A mistake or error resulting from unexpected environmental problems (13:17-21).

Communication Error - A mistake or error derived from the improper communication between members of a programming team or due to inappropriate system design specifications (13:17-21).

APPENDIX C

STRUCTURED INTERVIEW QUESTIONNAIRE

Responsiveness

1. What is responsiveness for an ECS change request?

1a. How is that requirement documented?

2. Is that requirement the SOP utilized for responsiveness or does there exist other guides?

2a. If other guides exist, what are they and how do they affect the responsiveness requirement?

3. What type of management structure exists to support the responsiveness requirement?

4. Does there exist a classification method of change requests? If so, what is it and how determined?

5. What is acceptable response intervals for the various types of change requests?

6. What actions are initiated upon a receipt of a change request in regards to other work in progress or waiting processing?

7. How is the criticality of a change request determined?

8. How is the associated corrective action priority established?

9. What actions are associated with making the corrective action release available to the user?

10. What practices are established to ensure effective communication with users?

11. What has been done to prevent and lessen the possibility of the formation of duplicative support organizations?

12. What is "real-time" change request resolution defined to be?

13. How are the priorities for all work determined and reevaluated on receipt of a new work requirement?

14. How is the importance of an ECS change request related to the weapon system and its operational impact?

15. What are the change request definition requirements for a software change?

16. What are time requirements associated with all evaluations?

17. How is error validity determined and when an error is determined invalid what disposition actions are initiated?

18. What testing is accomplished for corrective actions?

19. Is corrective action allowed by user organization?

19a. If so, what limitations exist on their corrective action capability and how is this enforced?

19b. What verification of user corrective action is performed?

19c. What is the relationship between user initiated corrective actions and the support organization's corrective action for a common change request?

20. What safeguards are utilized to prevent "crash" efforts on change requests?

21. What initial documentation requirements exist for a change request?

22. What are the requirements for correlation of a current change request to other actions that may be associated with that change request?

23. When a release is made of a corrective action to ECS, what are the documentation requirements?

24. Characterize typical problems encountered in ECS and how extensive?

25. Does there exist software structure requirements? If so, what are they?

Control

1. What control requirements exist and are they documented?

1a. Do the documented requirements reflect actual SOP? If not, what SOP are utilized?

2. How were the control requirements determined? What were the primary considerations?

3. What do the control requirements address?

4. Is there a single point of management for the ECS?

4a. If so, what is the extent of their authority?

4b. What is the relationship between the single point of management and the user?

4c. What are the main control functions of the single point of management?

5. To what extent does "management by reaction" characterize management's operation?

5a. What procedures are established to prevent management by reaction?

6. What internal control requirements have been established?

6a. Were these requirements determined jointly with the user? If so, to what extent was user participation and of what scope?

7. What controls are established over documentation, both original and updates?

8. How are control functions assigned and what is the responsibility distribution and relationships?

9. Do measurement standards exist to evaluate organization effectiveness?

9a. How were these standards determined?

10. Is your organization a centralization or decentralized function and why?

11. What is the user's role in your control requirements.?

Communication

1. What is the nature of communication between System Managers and the users?

2. What is the extent of management between user and System Manager?

3. Do breakdowns in communication occur and if so, what is their cause?

4. How critical is the initial information sent to the support organization? What requirements exist for that initial transmission?

5. What is the nature of communication lines between programmers and users? How is this ensured?

6. What emphasis is placed on communication with the user and how is this implemented?

7. What is the scope of the interface between user and System Manager?

8. Are communications channels vertical, horizontal, or what? Why?

9. What management structure supports the communication requirements of the organization?

10. How vital is communication with the user to the organization?

11. Is there a correspondence between life cycle of a problem and communication? Why?

Management

1. What are the key functions of the organization's management?

2. How clearly are the responsibilities within the organization and external organizations's delineated? What are these delineations and how enforced?

3. What is management's role?

4. How are management practices determined?

5. What requirements or procedures are in-being to assure single point of management?

Design

1. What requirements exist for the design of software corrective actions?

Planning

1. What planning is performed in support of the ECS?

2. What management practices are utilized to assure effective planning?

3. How are plans maintained?

4. Do long range plans exist and are they practical?

Documentation

1. Do shortcomings exist in documentation? If so, what practices are utilized to circumvent this problem?

2. What is the impact of documentation not being available?

3. What requirements are levied for the documentation of change requests?

4. How is the documentation of corrective actions performed?

5. Do standards for software documentation exist? Are they utilized?

6. Does there exist a correspondence between documentation and the reliability of an ECS?

7. Is support of ECS documentation dependent? How?

Requirements

1. Who is responsible for software requirements origination and validation?

2. What requirements exist for the definition, scope, and application of requirements?

3. To what extent are requirements subject to change and how frequently is this exercised?

4. What constitutes complete, consistent, traceable, and flexible requirements?

5. What is done to ensure that the user requirements are effectively interpreted by the support organization?

6. What is the correlation of user needs and design requirements?

7. What standards exist that are associated with the requirements, both for the user and the support organization?

Maintainability

1. How is ease of ECS maintenance determined?

2. How is the reliability of the ECS determined?

3. How are updates and modifications to ECS evaluated to determine impacts and increases in difficulty of maintenance?

4. How often is revision of the ECS performed to enhance maintainability?

5. Who performs the maintenance function?

User

1. What is the relationship between the user and the support organization?

2. What is the role of the user in the maintenance of ECS?

3. What concurrence and participation requirements are levied on users for software maintenance?

4. To what degree is the commitment of users to a software program important?

5. What is the relationship between requirements and the user?

6. What is the users responsibility for corrective actions?

7. How critical is user's involvment to the System Manager's activities?

Test

1. What role does testing play in ECS?

2. What is the criteria for performing tests for corrective action software?

Executive Steering Committee

1. What is the purpose of the organization's top leadership in regards to software?

2. Are management problems resulting from policy or lack of policy?

Personnel

1. Are personnel critical to the functioning of your organization? Why?

2. To what degree is your organization dependent on programmers?

3. What are the required qualifications for programmers?

4. How extensive and important is experience, continuity, and expertise?

5. What is the normal length of tenure of programmers?

6. What is the level of expertise?

7. What is the level of experience?

8. What is the mode of maintenance operation, contractor dependent or organic?

APPENDIX D

Q-GERT PROGRAM INSTRUCTIONS

```
GEN,WADE,ALC,3,5,1980,17,10,250,10000.,3,S,,5,(21)60,25*
SOU,1,0,1,D,M*
ACT,1,1,UF,1,1/PROBGEN,1*
ACT,1,2*
VAS,1,5,IN,1*
REG,2,1,1,P*
ACT,2,3,UN,8,2/EWALC,1,.05*
PAR,8,,0.,2.*
ACT,2,3,UN,9,3/PWALC,1.,.05*
PAR,9,,0.,24.*
ACT,2,3,(8).9*
STA,3/ARRIVAL,1,1,P,I*
VAS,3,1,UF,4*
ACT,3,4,(8).5*
ACT,3,5,(8).5*
REG,4,1,1,D*
VAS,4,2,CO,1*
ACT,4,6*
REG,5,1,1,D*
VAS,5,2,CO,2*
ACT,5,6*
REG,6,1,1,F*
ACT,6,7,(9)A1.EQ.1*
ACT,6,12,(9)A1.EQ.2*
REG,7,1,1,F*
ACT,7,8,(9)A2.EQ.1*
ACT,7,9,(9)A2.EQ.2*
REG,8,1,1,P*
ACT,8,17,(8).5*
ACT,8,10,(8).5*
REG,10,1,1,D*
VAS,10,2,CO,2*
ACT,10,9*
QUE,17/CALLOUT,0,,D,F*
ACT,17,18,UN,10,4/REVIEW,1*
PAR,10,,0.,8.*
STA,18/RESPONSE,1,1,D,I*
ACT,18,20,UF,5,11/WTDUTY,1*
QUE,9/DELAY,0,,D,F*
ACT,9,11,UF,5,5/WTDUTY,1*
STA,11/DELAY,1,1,D,I*
ACT,11,12*
QUE,12/MMMS,0,,P,F*
ACT,12,15,(8).9*
ACT,12,13,(8).1*
REG,13,1,1,F*
ACT,13,14,UN,8,6/CATIWALC,1,,A2.EQ.1*
ACT,13,15,UN,9,(9)A2.EQ.2*
```

```
SIN,14/WCATI,1,1,D,I*
SIN,15/WCATII,1,1,D,I*
REG,16,1,1,F*
ACT,15,19,UN,11,(9)A2.EQ.1*
PAR,11,,0.,.5*
ACT,16,19,UN,12,(9)A2.EQ.2*
PAR,12,,0.,72.*
STA,19/MIPCL,1,1,D,I*
ACT,19,20,UN,8,9/ASSIGN,1*
STA,20/MM-RT,1,1,D,I*
ACT,20,21,UN,9,10/PROBREV,1*
STA,21/CPSP,1,1,D,I*
VAS,21,3,UF,3*
ACT,21,25*
QUE,25/REL BL,0,,D,S/3*
VAS,25,4,UF,6*
ACT,25,26,UN,13,15/RELCYCLE,100*
PAR,13,,0.,8750.*
QUE,26,0,,D,S/3,(10)56*
ACT,21,22*
REG,22,1,1,F*
ACT,22,23,UN,9,13/CATI,1,,A2.EQ.1*
ACT,22,24,UN,14,14/CATII,1,,A2.EQ.2*
PAR,14,,0.,120.*
SIN,23/RESPONSE,1,1,D,I*
SIN,24/RESPONSE,1,1,D,I*
ACT,21,27,UN,9,12/REQSPT,1*
STA,27/MMECT,1,1,D,I*
ACT,27,29*
QUE,29/ENG DEV,0,,D,S/5*
ACT,29,31,UN,15,20/ODRV,100*
PAR,15,,0.,3240.*
QUE,31/WT CCB,0,,D,S/5,(10)36*
ACT,27,28,UN,15,16/DESKREV,1*
PAR,16,,0.,1.*
REG,28,1,1,P*
ACT,28,30,UF,2,17/SOUCHNG,1,.9*
ACT,28,32,UN,16,18/NO COU,1,.1*
QUE,30/CPCSB,0,,D,S/5*
ACT,30,32,UN,17,19/RECCM,1*
PAR,17,,0.,335.*
REG,32,1,1,P*
ACT,32,33,(8).1*
SIN,33/TRAS,1,1,D,I*
ACT,32,38,(8).9*
REG,38,1,1,P*
ACT,38,34,(8).1*
SIN,34/STOP,1,1,D,I*
```

```
ACT,58,35,(8).9*
STA,35/CCB,1,1,D,I*
ACT,35,59*
QUE,59/CCB,0,,D,S/5,(10)36*
MAT,36,5,59/37,31*
ACT,36,37,UN,17,20/CCBD,1*
REG,37,1,1,P*
ACT,37,38,(8).1*
SIN,38/NOTE,1,1,D,I*
ACT,37,39,(8).9*
STA,39/APP,1,1,D,I*
ACT,39,40*
REG,40,1,1,P*
ACT,40,44,(8).5*
ACT,40,41,(8).5*
QUE,41/HQAFLC,0,,D,S/5*
ACT,41,42,UN,18,21/CCBD,1*
PAR,18,,0.,1620.*
REG,42,1,1,P*
ACT,42,45,(8).9*
ACT,42,43,(8).1*
SIN,43/NOTE,1,1,D,I*
REG,44,1,1,P*
ACT,44,45,(8).5*
ACT,44,45,UN,17,(8).5*
STA,45/INHOUSE,1,1,PI*
ACT,45,46,(8).1*
SIN,46/PA,1,1,D,I*
ACT,45,60,(8).9*
REG,60,1,1,D*
ACT,60,47,UF,7,23/FIX TIME,1*
STA,47/FIX CHG,1,1,D,I*
ACT,47,49*
QUE,49/WT REL,0,,D,S/3,(10)56*
ACT,56,48,UN,19*
PAR,19,,0.,380.*
STA,48/PREDES,1,1,D,I*
ACT,48,50,UN,19*
STA,50/DETDES,1,1,D,I*
ACT,50,51,UN,19*
STA,51/C-T,1,1,D,I*
ACT,51,52,UN,19*
STA,52/VALID,1,1,D,I*
ACT,52,53,UN,19*
STA,53/KP,1,1,D,I*
ACT,53,54,UN,19
STA,54/CPCSB,1,1,D,I*
```

```
ACT,54,55*
QUE,55/WT REL,0,,D,S/3,(10)56*
MAT,56,3,49/57,55,26*
ACT,56,57,UN,17,25/DIST,1*
SIN,57/USER,1,1,D,I*
FIN*

*** NO ERRORS DETECTED IN INPUT DATA ***

*** EXECUTION WILL BE ATTEMPTED ***
```

```
      FUNCTION UF(IFN)
      COMMON/QVAR/NOE,NFTBU(100),NREL(100),NRELP(100),NREL2(100),NRUN,
     1NRUNS,NTC(100),PARAM(100,4),TBEG,TNOW,Y,ANR,AA,EC,X,ZZ,XZ,E,EE,KK
      GO TO (1,2,3,4,5,6,7),IFN
      IF(TNOW.EQ.0.)EC=0.
      IF(TNOW.EQ.0.)E=200.
      UF=(1./((E/4400.)-(EC/4400.)))
      Y=1./UF
      RETURN
      UF=1./.9
      X=0.
      AJ=ANR + 1.
      IF(AJ.GT.E) GO TO 20
      X=(1./(Y*AJ)) + X
      AJ=AJ+1.
      GO TO 10
      UF=UF*X
      RETURN
      I=TNOW/2190.
      UF=I+1
      RETURN
      UF=2
      AA=TNOW/168.
      AII=AA
      AA=(AA-AII)*168.
      IF(AA.LT.105.)GO TO 50
      UF=1
      GO TO 60
      AA=TNOW/24.
      AII=AA
      AA=(AA-AII)*24.
      IF(AA.GE.9.)UF=1.
      RETURN
      IF(AA.GE.105.) GO TO 70
      UF=24.-AA
      GO TO 80
      UF=168.-AA
      RETURN
      UF=0.
      AIII=TNOW/2190. + 1.
      AIII=AIII*2190.
      IF(TNOW.NE.AIII) GO TO 90
      EC=NTC(25)-EC
      ANR=E-EC
      EE=ANR
      KK=1.
      GO TO 95
      KK=0.
      RETURN
      YY=(E/4400.)-(EC/4400.)
```

```
XX=1./.9
ZZ=0.
XZ=0.
AJJ=ANR + 1.
IF(AJJ.GT.E) GO TO 40
ZZ=(1./(YY*AJJ) ) + ZZ
XZ=((1./(YY*AJJ))**2)+XZ


AJJ=AJJ+1.
GO TO 30
A=XX*ZZ
B=((XX**2)*XZ)
ALP=((A**2)/B)
BETA=(B/A)
AK=ALP
K=ALP
FK=K
GAM=0.
XMAX=100000.
XMIN=0.
IF(K)103,103,101
P=1.0
DO 102 I=1,K
P=P*RANF(0.0)
GAM=-1*(ALOG(P))
D=AK-FK
IF(D-.015)110,110,103
IF(D-.985)106,105,105
W=1.0
GO TO 109
AAA=1.0/D
BB=1.0/(1.0-D)
XA=(RANF(0.0))**AAA
YA=(RANF(0.0))**BB +XA
IF(YA-1.0)108,106,107
W=XA/YA
YA=-1*(ALOG(RANF(0.0)))
GAM=GAM + W *YA
GAMA=GAM*BETA
IF(GAMA-XMIN)121, 124,122
GAMA=XMIN
GO TO 124
IF(GAMA-XMAX)124, 124,123
GAMA=XMAX
UF=GAMA
IF(KK.EQ.1.) E=EE
RETURN
END
```

```
GEN,WADE,TAC,3,5,1980,20,7,200,10000.,3,S,(21)43,16*
SOU,1,0,1,D,M*
ACT,1,1,UF,1,1/PROBGEN,1*
ACT,1,2,UF,3,2/CORRACT,1*
STA,2/CPCSB,1,1,P,I*
ACT,2,3,UF,2,3/DISAP,1,.5*
ACT,2,4,UF,2,4/APP,1,.5*
SIN,3/STOP ACT,1,1,D,I*
STA,4/CHNG ASSESS,1,1,P,I*
ACT,4,7,(8).5*
ACT,4,5,(8).5*
STA,5/IMP CHNG,1,1,D,I*
ACT,5,6,UF,4,5/FIX TIME,1*
SIN,6/CLOSE PROB,1,1,D,I*
QUE,7/PR10,0,,P,F*
ACT,7,8,UN,5,(8).5*
PAR,5,,0.,24.*
ACT,7,11,(8).5*
STA,8/TAF CCB,1,1,P,I*
ACT,8,11,(8).5*
ACT,8,9,(8),.5*
QUE,9/CHNG IMP,0,,D,F*
ACT,9,10,UF,4,6/FIX TIME,1*
SIN,10/DIST CHNG,1,1,D,I*
STA,11/TAFIG,1,1,D,I*
ACT,11,12,UN,5,7/CHNGDIST,1*
STA,12/EVAL,1,1,D,I*
ACT,12,13,UN,6,8/RQMTS,1*
PAR,6,,0.,158.*
REG,13,1,1,P*
ACT,13,14,(8).5*
ACT,13,15,(8).5*
STA,14/SM-IM,1,1,D,I*
ACT,14,15*
QUE,15/TAFIG,0,,D,F*
ACT,15,16,UN,5,9/AGENDA,1*
STA,16/TAF CCB,1,1,P,I*
ACT,16,17,UN,5,10/DISAP,1,.5*
ACT,16,18,UN,5,11/APP,1,.5*
SIN,17/ORIG,1,1,D,I*
REG,18,1,1,P*
ACT,18,34,(8).5*
ACT,18,19,(8).5*
STA,19/IMP,1,1,D,I*
ACT,19,20,UF,4,12/FIX TIME,1*
REG,20,1,1,P*
ACT,20,25,(8).5*
ACT,20,21,(8).5*
REG,21,1,1,P*
ACT,21,30,(8).5*
ACT,21,22,(8).5*
```

```
STA,22/JTF,1,1,D,I*
ACT,22,23,UN,7,13/JOINTTEST,1*
PAR,7,,0.,720.*
REG,23,1,1,P*
ACT,23,24,(8).5*
ACT,23,25,(8).5*
STA,25/TEST FAIL,1,1,D,I*
ACT,25,29*
STA,24/CERTIFY,1,1,D,I*
ACT,24,31*
STA,30/NO TEST,1,1,D,I*
ACT,30,31*
STA,26/TSISC,1,1,D,I*
ACT,26,27,UN,7*
STA,27/TEST EVAL,1,1,D,I*
ACT,27,28*
REG,28,1,1,P*
ACT,28,29,(8).5*
ACT,28,31,(8).5*
QUE,29/MOD RQMTS,0,,0,F*
ACT,29,20,UN,8*
PAR,8,,0.,48.*
REG,34,1,1,P*
ACT,34,35,(8).5*
ACT,34,36,(8).5*
STA,35/CLASSII,1,1,D,I*
ACT,35,36,UN,5,16/CIICR,1*
STA,36/JSB,1,1,D,I*
ACT,36,37,UN,5*
STA,37/JSB ACT,1,1,P,I*
ACT,37,35,(8).5*
ACT,37,38,(8).5*
REG,38,1,1,P*
ACT,38,39,UN,9,(8).5*
PAR,9,,0.,336.*
ACT,38,41,UN,9,(8).5*
REG,39,1,1,P*
ACT,39,12,(8).5*
ACT,39,40,(8).5*
SIN,40/STOP,1,1,D,I*
REG,41,1,1,P*
ACT,41,42,(8).5*
ACT,41,43,(8).5*
SIN,42/HIGHER CCD,1,1,D,I*
STA,43/JSTND CHNG,1,1,D,I*
ACT,43,22*
QUE,31/CERT B-L,0,,0,F*
ACT,31,32,UN,5,14/CHNG BL,1*
```

```
STA,32/RELE,1,1,D,I*
ACT,32,33,UN,9,15/DIST,1*
SIN,33/USER,1,1,D,I*
FIN*

*** NO ERRORS DETECTED IN INPUT DATA ***

*** EXECUTION WILL BE ATTEMPTED ***
```

```
 FUNCTION UF(IFN)
 COMMON/QVAR/NDE,NFTBU(100),NREL(100),NRELP(100),NREL2(100),NRUN,
1NRUNS,NTC(100),FAFAM(100,4),TBEG,TNOW,Y,ANR,EC,ZZ,XZ,E
 GO TO (1,2,3,4),IFN
 IF(TNOW.EQ.0.)ANR=20'.
 IF(TNOW.EQ.0.)EC=0.
 IF(TNOW.EQ.0.)E=200.
 UF=(1./((E/4400.)-(EC/4400.)))
 Y=1./UF
 RETURN
 UF=1./.9
 X=0.
 AJ=ANR +1.
 IF(AJ.GT.E) GO TO 20
 X=(1./(Y*AJ)) + X
 AJ=AJ + 1.
 GO TO 10
 UF=UF*X
 RETURN
 UF=0
 IF(TNOW.EQ.0.)ANR=20'.
 ANR=ANR-1.
 EC=E-ANR
 RETURN
 YY=(E/4400.)-(EC/440'.)
 XX=1./.9
 AJJ=ANR + 1.
 XZ=0.
 ZZ=0.
 IF(AJJ.GT.E) GO TO 4'
 ZZ=(1./(YY * AJJ)) + ZZ
 XZ=(1./(YY*AJJ))**2 +XZ
 AJJ=AJJ + 1.
 GO TO 30
 CONTINUE
 A=XX*ZZ
 B=((XX**2)*XZ)
 ALP=((A**2)/B)
 BETA=(B/A)
 AK=ALP
 K=ALP
 FK=K
 GAM=0.
 XMAX=100000.
 XMIN=0.
 IF(K)103,103,101
 P=1.0
 DO 102 I=1,K
 P=P*RANF(0.0)
```

```
GAM=-1*(ALOG(P))
D=AK-FK
IF(D-.815)110,110,107
IF(D-.935)106,105,107
W=1.0
GO TO 109
AA=1.0/D
BB=1.0/(1.0-D)

XA=(RANF(0.0))**AA
YA=(RANF(0.0))**BB +XA
IF(YA-1.0)108,108,107
W=XA/YA
YA=-1.*(ALOG(RANF(0.0)))
GAM=GAM + W *YA
GAMA=GAM*BETA
IF(GAMA-XMIN)121,124,122
GAMA=XMIN
GO TO 124
IF(GAMA-XMAX)124,124,123
GAMA=XMAX
UF=GAMA
E=E-1.
RETURN
END
```

```
GEN,WAGE,NAS,3,5,1981,17,4,230,10000.,3,S,,4,(21)54,24*
SOU,1,0,1,D,M*
ACT,1,1,UF,1,1/PROBGEN,1*
ACT,1,2*
STA,2/IBM TSO,1,1,D,I*
VAS,2,1,IN,1*
ACT,2,3,UF,2,2/ISOPROB,1*
REG,3,1,1,P*
ACT,3,4,(8).125*
ACT,3,8,(8).125*
ACT,3,10,(8).5*
ACT,3,11,(8).25*
REG,4,1,1,D*
VAS,4,2,CO,5*
ACT,4,7*
REG,8,1,1,D*
VAS,8,2,CO,6*
ACT,8,7*
REG,10,1,1,D*
VAS,10,2,CO,7*
ACT,10,7*
REG,11,1,1,P*
ACT,11,12,(8).25*
ACT,11,14,(8).25*
ACT,11,16,(8).25*
ACT,11,17,(8).25*
REG,12,1,1,D*
VAS,12,2,CO,1*
ACT,12,7*
REG,14,1,1,D*
VAS,14,2,CO,2*
ACT,14,7*
REG,16,1,1,D*
VAS,16,2,CO,4*
ACT,16,7*
REG,17,1,1,D*
VAS,17,2,CO,3*
ACT,17,7*
QUE,7/PROBID,0,,D,S/1*
ACT,7,33*
STA,33/IBMTIME,1,1,D,I*
ACT,33,20,UF,4*
REG,20,1,1,F*
ACT,20,22,,,23/CR,1,,A2.EQ.5*
ACT,20,31,(9)A2.EQ.6*
ACT,20,33,UN,3,24/TSO BC,1,,A2.EQ.7*
PAR,3,,,24.*
ACT,20,21,UN,5,(9)A2.LE.4*
SIN,21/O-L PPT,1,1,D,I*
QUE,31,,,D,F*
ACT,31,32,UF,3,7/FIX,1*
```

```
STA,32/OASCB A,1,1,P,I*
ACT,32,33,UN,6,8/APP,1,.5*
PAR,6,,0.,48.*
SIN,33/CLOSE,1,1,D,I*
ACT,32,34,UN,5,9/DISAP,1,.5*
STA,34/REMO P,1,1,D,I*
ACT,34,35,UN,5*
STA,35/TRO BD,1,1,P,I*
ACT,35,37,,,12/T-F,1,.5*
ACT,35,36,,,13/PERM,1,.5*
REG,36,1,1,P*
ACT,36,37,(8).5*
ACT,36,38,(8).5*
QUE,37/SAS,0,,D,S/1*
ACT,37,45,UF,5,10/FIX,1*
STA,45/WT OASCB,1,1,D,I*
ACT,45,46*
ACT,45,43,UN,5,17/OASCB,1*
STA,38/GEN DR,1,1,P,I*
ACT,38,40,(8).334*
ACT,38,39,(8).333*
ACT,38,22,(8).333*
REG,39,1,1,P*
ACT,39,40,UN,8,(8).5*
ACT,39,42,UN,8,(8).5*
STA,42/WR,1,1,D,I*
VAS,42,3,CO,1*
ACT,42,45*
ACT,42,43,UN,5,14/APP WV,1*
QUE,43/PAT DEV,0,,D,S/1*
ACT,43,41,UF,5,11/FIX,1*
STA,41/TRO BD,1,1,D,I*
ACT,41,43,UN,5,16/PAT WT,1*
ACT,41,46*
QUE,22/GEN CR,0,,D,F*
ACT,22,23,UN,3,3/LIII CM,1*
PAR,3,,0.,336.*
STA,23/EVAL,1,1,D,I*
ACT,23,24,UN,9,4/EVAL,1*
PAR,9,,0.,4320.*
STA,24/LIIICCB,1,1,P,I*
ACT,24,25,(8).5*
ACT,24,29,(8).5*
QUE,25/RETURN,0,,D,F*
ACT,25,26,UN,3,5/ROUTE,1*
STA,26/APPEAL,1,1,P,I*
ACT,26,27,(8).5*
SIN,27/CLOSE,1,1,D,I*
ACT,26,28,(8).5*
REG,28,1,1,P*
ACT,28,27,(8).5*
ACT,28,29,(8).5*
```

```
QUE,29/TSO 9D,6,,D,F*
ACT,29,30,UF,5,6/FIX,1*
STA,30/OASC9 W,1,1,D,I*
ACT,31,46*
ACT,30,43,UN,5,15/CR WAIT,1*
QUE,43/OASC9,3,,D,S/1*
ACT,43,54*
STA,54/OASC9,1,1,F,I*
ACT,54,44,(9)A3.EQ.1*
ACT,54,47,(9)A3.NE.1*
REG,44,1,1,P*
ACT,44,22,(8).333*
ACT,44,40,(8).333*
ACT,44,47,(8).334*
QUE,47/APPACT,6,,D,S/1,(10)48*
QUE,46/DOD-PGM,6,,D,S/1,(10)48*
MAT,48,1,47/49,46*
ACT,48,49,UN,5,19/MMCRT,1*
STA,49/MMCRT,1,1,D,I*
ACT,49,50,UF,3,20/REL SCH,100*
STA,50/REL,1,1,D,I*
ACT,50,51,UN,5,21/PGM9D,1*
STA,51/SW REL,1,1,D,I*
ACT,51,52,UN,5,22/DIST,1*
SIN,52,1,1,D,I*
FIN*
```

```
FUNCTION UF(IFN)
COMMON/QVAR/NDE,NFTBU(100),NREL(100),NRELP(100),NREL2(100),NRUN,
1NRUNS,NTC(100),PARAM(100,4),TBEG,TNOW,EC,ANR,Y,ZZ,XZ,E
GO TO (1,2,3,4,5),IFN
IF(TNOW.EQ.0.)EC=0.
IF(TNOW.EQ.0.)E=200.
IF(TNOW.EQ.0.)ANR=200.
UF=(1./((E/4400.)-(EC/4400.)))
Y=1./UF
RETURN
UF=1./.9
IF(TNOW.EQ.0.)ANR=200.
ANR=ANR-1.
AJ=ANR + 1.
X=0.
IF(AJ.GT.E)GO TO 20
X=(1./(Y*AJ))+X
AJ=AJ +1.
GO TO 10
UF=UF*X
 RETURN
UF=100.
RETURN
UF=0.
EC=E-ANR
RETURN
YY=(E/4400.)-(EC/4400.)
XX=1./.9
AJJ=ANR + 1.
XZ=0.
ZZ=0.
IF(AJJ.GT.E) GO TO 40
ZZ=(1./(YY*AJJ))+ZZ
XZ=(1./(YY*AJJ)**2)+XZ
AJJ=AJJ+1.
GO TO 30
A=XX*ZZ
B=((XX**2)*XZ)
ALP=((A**2)/B)
BETA=(B/A)
AK=ALP
K=ALP
FK=K
GAM=0.
XMAX=100000.
XMIN=0.
PRINT *,A,B,ALP,BETA,AK,K,FK
IF(K)103,103,101
P=1.0
DO 102 I=1,K
P=P*RANF(0.0)
```

```
GAM=-1*(ALOG(P))
D=AK-FK
IF(D-.015)110,110,104
IF(D-.985)106,105,105
W=1.0
GO TO 109

AA=1.0/D
BB=1.0/(1.0-D)
XA=(RANF(0.0))**AA
YA=(RANF(0.0))**BB +XA
IF(YA-1.0)108,108,107
W=XA/YA
YA=-1*(ALOG(RANF(0.0)))
GAM=GAM + W *YA
GAMA=GAM*BETA
IF(GAMA-XMIN)121,124,122
GAMA=XMIN
GO. TO 124
IF(GAMA-XMAX)124,124,123
GAMA=XMAX
UF=GAMA
E=E-1.
RETURN
END
```

APPENDIX E

FORTRAN PRINCIPLE ANALYSIS PROGRAM

```
0155601

STATION ID  -AG
04/11/80 create  8.341  2127

user id -80A024,PC41,WP1186
SYSTEM ?
**ALL USERS CHECK CODE-A-PHONE MESSAGE (77605)


009-SYSTEM UNKNOWN
SYSTEM ?FORT
OLD OR NEW-OLD FACTOR
READY
*LIST

010 DIMENSION FAC(24,13,13),REL(13,13)
015 CHARACTER A,B
020 DO 20 I=1,24,1
030 DO 30 J=1,13,1
040 DO 40 K=1,13,1
050 FAC(I,J,K)=0.
060 REL(J,K)=0.
070 40 CONTINUE
080 30 CONTINUE
090 20 CONTINUE
100 50 PRINT,"WHAT IS THE AUTHOR'S NUMBER?"
110 READ,I
120 IF(I.EQ.100) GO TO 60
129 PRINT,"WHAT IS THE PRINCIPLE - MAIN,EXEC,PLAN,CHAN,MGMT,DESI,"
130 PRINT,"RQMT,COMM,DOCU,USER,PERS,TEST - INVOLVED?"
131 READ,A
132 IF(A.EQ.'MAIN') J=1
133 IF(A.EQ.'EXEC')J=2
134 IF(A.EQ.'PLAN')J=3
135 IF(A.EQ.'CHAN')J=4
136 IF(A.EQ.'CONT')J=5
137 IF(A.EQ.'MGMT')J=6
138 IF(A.EQ.'DESI')J=7
139 IF(A.EQ.'RQMT')J=8
140 IF(A.EQ.'COMM')J=9
```

```
141 IF(A.EQ.'DOCU')J=10
142 IF(A.EQ.'USER')J=11
143 IF(A.EQ.'PERS')J=12
144 IF(A.EQ.'TEST')J=13
145 PRINT, "WHAT IS THE FACTOR?"
146 READ,B
147 IF(B.EQ.'MAIN')K=1
148 IF(B.EQ.'EXEC')K=2
149 IF(B.EQ.'PLAN')K=3
150 IF(B.EQ.'CHAN')K=4
151 IF(B.EQ.'CONT')K=5
152 IF(B.EQ.'MGMT')K=6
153 IF(B.EQ.'DESI')K=7
154 IF(B.EQ.'RQMT')K=8
155 IF(B.EQ.'COMM')K=9
156 IF(B.EQ.'DOCU')K=10
157 IF(B.EQ.'USER')k=11
158 IF(B.EQ.'PERS')K=12
159 IF(B.EQ.'TEST')K=13
170 FAC(I,J,K)=FAC(I,J,K)+1.
180 GO TO 50
190 60 DO 70 I=1,24,1
200 DO 80 K=1,13,1
210 C=0.
220 DO 90 J=1,13,1
230 C=FAC(I,J,K)+C
240 90 CONTINUE
245 IF(C.EQ.0.) GO TO 80
250 DO 100 J=1,13,1
260 FAC(I,J,K)=FAC(I,J,K)/(C*24.)
270 100 CONTINUE
280 80 CONTINUE
290 70 CONTINUE
300 DO 110 K=1,13,1
310 DO 120 J=1,13,1
320 DO 130 I=1,24,1
330 REL(J,K)=REL(J,K)+FAC(I,J,K)
340 130 CONTINUE
350 120 CONTINUE
360 110 CONTINUE
370 PRINT 140,((REL(I,J),I=1,13),J=1,7)
380 140 FORMAT(//,2X,7(2X,F6.4))
382 PRINT 150,((REL(I,J),I=1,13),J=8,13)
384 150 FORMAT(//,2X,6(2X,F6.4))
390 STOP
400 END

ready

*
```

APPENDIX F

DYNAMO MODEL

```
0010* SOFTWARE MANAGEMENT FACTOR
0020NOTE MANAGEMENT PRINCIPLES INTERRELATIONSHIP FACTORS
0030C AA=.01
0040C AB=.02
0050C AC=.03
0060C AD=.04
0070C AE=.05
0080C AF=.06
0090C AG=.07
0100C AH=.08
0110C AJ=.09
0120C AK=.1
0130C AL=.11
0140C AM=.12
0150C AN=.13
0160C AO=.14
0170C AP=.15
0180C AQ=.16
0190C AR=.18
0200C AS=.19
0210C AT=.2
0220C AU=.21
0230C AV=.24
0240C AW=.28
0250C AX=.29
0260C AY=.3
0270C AZ=.34
0280C AAA=.37
0290C AAB=.38
0300C AAC=.43
0310C AAD=.47
0320C AAE=.48
0330C AAF=.56
0340C AAG=.6
0350C AAH=.63
0360C AAI=.65
0370C AAJ=.7
0380C AAK=.74
0390NOTE UNITARY FACTORS
0400C AAL=5
0410C AAM=8
0420C AAN=6
0430C AAO=9
0440C AAP=4
0450NOTE MANAGEMENT PRINCIPLES VALUES
0460NOTE EXECUTIVE STEERING COMMITTEE
0470A ESC.K=(AB*MAI)+(AAH*ESI)+(AO*PLI)+(AS*CNI)+
0480X (AA*TEI)+(AA*REI)
```

```
0490NOTE MAINTAINABILITY
0500A MA.K=(AM*PLA.K)+(AB*CHI)+(AD*CNT.K)+(AZ*DEI)+
0510X (AH*CMI)+(AS*DOI)+(AA*USE.K)+(AT*PER.K)
0520NOTE PLANNING
0530A PLA.K=(AAJ*ESC.K)+(AD*TEI)+(AK*DOI)+(AF*USE.K)
0540NOTE CHANGE RATE
0550A CHR.K=(AO*PLA.K)+(AAE*TES.K)+(AW*DES.K)+(AJ*REQ.K)
0560X +(AA*DOC.K)
0570NOTE CONTROL
0580A CNT.K=(AB*ESC.K)+(AAK*PLA.K)+(AF*PEI)+(AL*TEI)+
0590X (AF*REI)+(AA*DOI)
0600NOTE PERSONNEL
0610A PER.K=(AL*CHI)+(AD*TEI)+(AAB*MGI)+(AY*CMI)+(AD*DOI)+
0620X (AN*USE.K)
0630NOTE TESTING
0640A TES.K=(AAA*ESC.K)+(AH*PLA.K)+(AA*CHI)+(AR*CNT.K)+(AK*TEI)+
0650X (AH*MGT.K)+(AL*REQ.K)+(AG*USE.K)
0660NOTE MANAGEMENT
0670A MGT.K=(AD*ESC.K)+(AAG*TEI)+(AU*REQ.K)+(AC*DOC.K)+(AM*USE.K)
0680NOTE DESIGN
0690A DES.K=(AE*CHI)+(AO*PER.K)+(AAD*DEI)+(AT*REQ.K)+(AO*CMI)
0700NOTE REQUIREMENT
0710A REQ.K=(AD*MA.K)+(AV*ESC.K)+(AX*CNT.K)+(AAC*MGI)
0720NOTE COMMUNICATION
0730A CMM.K=(AA*PLA.K)+(AA*CNT.K)+(AB*PER.K)+(AP*DOC.K)
0740X +(AAI*USE.K)+(AQ*TES.K)
0750NOTE DOCUMENTATION
0760A DOC.K=(AE*MA.K)+(AJ*CNT.K)+(AAH*DES.K)+(AC*REQ.K)+(AT*DOI)
0770NOTE USERS
0780A USE.K=(AB*ESC.K)+(AQ*CHI)+(AK*MGI)+(AB*DEI)+(AB*CMI)+
0790X (AM*DOI)+(AAF*USI)
0800NOTE INITIAL VALUES OF MANAGEMENT PRINCIPLES VARIABLES
0810C MAI=1
0820C TEI=1
0830C CNI=1
0840C ESI=1
0850C PLI=1
0860C REI=1
0870C CHI=1
0880C DEI=1
0890C CMI=1
0900C DOI=1
0910C PEI=1
0920C MGI=1
0930C USI=1
0940NOTE INITIAL FAILURE LEVEL
0950L ILF.K=ILF.J-(DT)(FR.JK)
0960N ILF=200
0970NOTE FAILURE RATE
0980R FR.KL=CHR.K*ILF.K*FRF
0990C FRF=.04
```

```
1000NOTE FAILURE RATE FRACTION BASED ON 8 PER WEEK
1010NOTE SOFTWARE ENGINEERING
1020L MME.K=MME.J+(DT)(FR.JK-RR.JK)
1030N MME=0
1040NOTE REVIEW RATE
1050R RR.KL=(MME.K*RRF)/MRF.K
1060C RRF=.05
1070NOTE REVIEW RATE FRACTION BASED ON 4 HOURS TO REVIEW
1080NOTE MANAGEMENT REVIEW FACTORS
1090A MRF.K=(REQ.K+DOC.K+MA.K+DES.K+PER.K)/AAL
1100NOTE COMPUTER PROGRAM SCREENING PANEL
1110L CPS.K=CPS.J+(DT)(RR.JK-CR.JK)
1120N CPS=0
1130NOTE COORDINATION RATE
1140R CR.KL=(CPS.K*CRF)/COF.K
1150C CRF=.025
1160NOTE COORDINATION RATE FRACTION BASED ON 8 HRS TO COORDINATE
1170NOTE COORDINATION FACTORS
1180A COF.K=(MGT.K+USE.K+PER.K+TES.K+DOC.K+CNM.K+DES.K+REQ.K)/AAM
1190NOTE COMPUTER PROGRAM CONFIGURATION SUB-BOARD
1200L CPC.K=CPC.J+(DT)(CR.JK-DR.JK)
1210N CPC=0
1220NOTE DISPOSITION RATE
1230R DR.KL=(CPC.K*DRF)/DF.K
1240C DRF=.025
1250NOTE DISPOSITION RATE FRACTION BASED ON 8 HRS TO EVALUATE
1260NOTE DISPOSITION FACTORS
1270A DF.K=(USE.K+PER.K+REQ.K+CNM.K+CNT.K+PLA.K)/AAN
1280NOTE CORRECTION ACTION
1290L CA.K=CA.J+(DT)(DR.JK-CAR.JK)
1300N CA=0
1310NOTE CORRECTIVE ACTION RATE
1320R CAR.KL=(CA.K*CAF)/CF.K
1330C CAF=.005
1340NOTE CORRECTIVE ACTION FRACTION BASED ON 1 PER WEEK
1350NOTE CORRECTIVE ACTION FACTORS
1360A CF.K=(DES.K+CNM.K+DOC.K+PER.K+REQ.K+MA.K+MGT.K+
1370X TES.K+USE.K)/AAO
1380NOTE CONFIGURATION CONTROL BOARD
1390L CCB.K=CCB.J+(DT)(CAR.JK-CDR.JK)
1400N CCB=0
1410NOTE CONFIGURATION CONTROL BOARD DIRECTIVE RATE
1420R CDR.KL=(CCB.K*CDF)/CMF.K
1430C CDF=.05
1440NOTE CCB FRACTION BASED ON WEEKLY MEETING OF TEN ITEMS
1450NOTE CCB MANAGEMENT FACTORS
1460A CMF.K=(USE.K+CNM.K+PLA.K+CNT.K)/AAP
1470NOTE SOFTWARE RELEASE
1480L REL.K=REL.J+(DT)(CDR.JK-SRR.JK)
1490N REL=0
1500NOTE SOFTWARE RELEASE RATE
```

```
1510R SRR.KL=(REL.K*SRF)/SF.K
1520C SRF=.025
1530NOTE RELEASE FRACTION BASED ON TWO WEEKS TO RELEASE SOFTWARE
1540NOTE SOFTWARE RELEASE FACTORS
1550A SF.K=(CNT.K+DOC.K+PER.K+USE.K+REQ.K)/AAL
1560PLOT MME=M/CPS=C/CPC=P/CA=A/CCB=B/REL=R
1570SPEC DT=2/LENGTH=208/PLTPER=2
1580RUN
```

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